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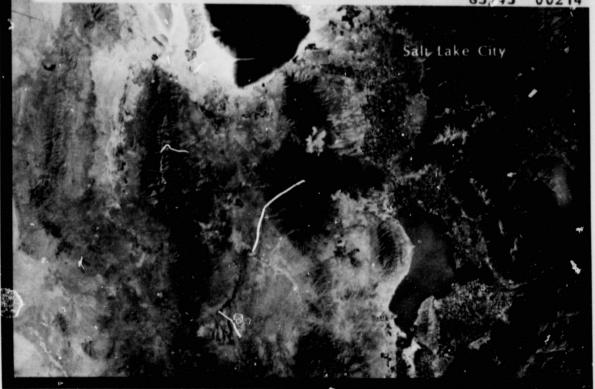
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(E83-10214) INVENTORY AND ANALYSIS OF RANGELAND RESOURCES OF THE STATE LAND BLOCK ON PARKER MOUNTAIN, UTAH (Utah Univ.) HC A08/MF A01 CSCL 08B

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UNIVERSITY OF UTAH RESEARCH INSTITUTE

Salt Lake City

ORIGINAL PAGE COLOR PHOTOGRAPH

# RESOURCES OF THE STATE LAND BLOCK ON PARKER MOUNTAIN, UTAH

CRSC Report 82-6

Original photography may be purchased from ENOS Data Center Sioux Falls, SD 57128

By

Richard A. Jaynes

Center for Remote Sensing and Cartography University of Utah Research Institute 420 Chipeta Way, Suite 190 Salt Lake City, Utah 84108

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National Aeronautics and Space Administration (Grant NAGW-95)

#### ORIGINAL PAGE COLOR PHOTOGRAPH



#### PARKER MOUNTAIN STATE LAND BLOCK

The photograph above is an enlargement of a Landsat false-color composite. Landsat imagery simulates color infrared photography, making aspen forests appear as bright red patches. Features such as Dry Wash, Parker Lake, and Parker Knoll are readily visable on the image. Approximate scale is 1:150,000.

The State of Utah owns and manages a 45,000 acre block of rangeland on Parker Mountain in south central Utah. Information regarding the nature and distribution of rangeland resources is needed to provide an effective data base for management. High altitude color infrared (CIR) photography was interpreted to provide an 1:24,000 overlay to U.S.G.S. topographic maps. The inventory and analysis of rangeland resources was augmented by the digital analysis of Landsat multispectral scanner (MSS) data.

Various combinations of vegetation cover, surface geology, and slope aspect often led to the confusion of a short growth form of mountain big sagebrush with black sagebrush. In addition, some silver sagebrush areas were spectrally and visually similar to big sagebrush vegetation cover. Field observations and ancillary data provided solutions to most sources of interpretive confusion.

Available geology, soils, and precipitation maps were used to sort out areas of confusion on the CIR photography. The map overlay from photo interpretation was also prepared with reference to print maps developed from Landsat MSS data. The resulting map overlay has a high degree of interpretive and spatial accuracy. The following major vegetation cover types were identified: aspen forest; tall growth form mountain big sagebrush; short growth form mountain big sagebrush; black sagebrush; mountain silver sagebrush; and wetland.

Initial assessment of Landsat MSS mapping accuracy showed an unacceptable level of confusion between the several sagebrush types in different portions of the study area. It was found that this confusion could largely be corrected by introducing ancillary data. Boundaries from geology, soils, and precipitation maps, as well as field observations, were digitized and pixel classes were adjusted according to the location of pixels with particular spectral signatures with respect to such boundaries. The resulting map, with six major cover classes, has an overall accuracy of 89%. Overall accuracy was 74% when these six classes were expanded to 20 classes.

This project has permitted a close evaluation of the relative merits of mapping rangeland resources from CIR photo interpretation and from MSS digital data. It was concluded that best results are obtained when both approaches are used in tandem; each approach has certain inherent disadvantages which are to a large extent corrected by utilizing the other approach.

The technical report accompanying the Parker Mountain maps includes management recommendations regarding field investigations, vegetation modifications, and grazing management. Management prescriptions and treatment schedules should be developed for each pasture, and compiled in a revised management plan. Vegetation maps and CIR photography should be used in selecting permanent field study sites for monitoring range condition and trend, utilization, and production. Recommended range improvements include fencing, seeding aspen understories, and sagebrush control and seeding. Grazing management should continue under a rotation-deferred system, with rest rotation during an initial ten-year pasture treatment cycle. It was concluded that livestock carrying capacity in the study area could be at least doubled over the next ten years, with modest investments in range improvement treatments.

#### **ACKNOWLEDGMENTS**

Significant cooperation and assistance from a variety of sources was received in the performance of this rangeland resource inventory and analysis. Appreciation is extended to the following individuals for the assistance indicated:

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Lars Rasmussen, Walter Bleak, Horace Andrews (retired), Hal Swensen, and Randy Bradbury, U.S. Soil Conservation Service, obtaining back-ground management information and performing field work;

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Applications of Landsat digital data were carried out by John Merola of the Center for Remote Sensing and Cartography.

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#### INTRODUCTION

The Parker Mountain State Land Block is one of the largest tracts of state-owned land in Utah. The area occupies over 45,000 acres located primarily in Piute County with portions in Wayne and Garfield Counties. Its resources are valued by livestock operators, wildlife and recreation enthusiasts, ari energy developers. As the managing authority for the area, the Utah Division of State Lands and Forestry is interested in acquiring an assessment of the natural resource potential on Parker Mountain to aid in accomplishing optimum multiple use management of such resources.

#### Objectives and Purposes of the Study

The primary objective of this study has been to prepara a map of rangeland vegetation communities and range improvements on the Parker Mountain State Land Block, utilizing color infrared aerial photography. The photo interpretations and field observations made in connection with this study have also been integrated with existing information regarding management practices, soils, geology, and vegetation communities. An additional objective has been to explore the feasibility of using Landsat satellite imagery to augment the analysis and mapping of resources. The primary purpose of the rangeland inventory and analysis is to provide a basic spatially-oriented range management information base for use in developing future grazing management plans for grazing permittees. This study will also aid in the process of land use planning on Parker Mountain so that range improvements will be located in areas where they are needed most, where they are most likely to be successful, and where conflict with other use interests will be minimized.

The Parker Mountain State Land Block is one of a number of land blocks for which resource information is needed to increase management effectiveness. Furthermore, as the State of Utah investigates the exchange and selection of land under Project B.O.L.D. to accomplish further blocking up of state-own tracts, techniques will be needed to permit efficient acquisition of resource management information. The techniques used in this study could be applied to any existing or potential block of state land in Utah since fairly recent high altitude color infrared aerial photography is available for almost all areas in the state. In addition, other low cost analytical materials such as black and white photography, and orthophoto quadrangles are also available for most areas. Thus, this study will provide a basis for evaluating the cost-effectiveness of inventorying and analyzing rangeland resources in the manner outlined below. Since recent Landsat imagery and multispectral digital data are available for all areas in the state, the feasibility of utilizing such data and imagery to map vegetation resources has also been explored in this study.

#### Study Area

Technically speaking, the Parker Mountain State Land Block includes 45,546.68 acres of rangeland, and comprises the following legal land descriptions:

Piute County	Wayne County
T.28S.,R.1W., S.L.B.& M.	T.28S.,R.1E., S.L.B.& M.
Sections 34, 35, 36: All.	Sections 31, 32: All.
T.29S.,R.1W., S.L.B.& M.	T.29S.,R.1E., S.L.B.& M.
Sections 1, 2, 3, 10: All; Sections 11, 12, 13, 14: All; Sections 15, 16, 21, 22: All;	Sections 5, 6, 7, 8: All; Sections 17, 18, 19, 20: All; Sections 29, 30, 31, 32: All.

#### Piute County

T.29S., R. 1W., S.L.B. & M. (cont'd)

Sections 23, 24, 25, 26: All; Sections 27, 28, 32, 33: All; Sections 34, 35, 36: All;

#### T.30S.,R.1W., S.L.B.& M.

Sections 1, 2, 3, 4: All; Sections 9, 10, 11, 12: All; Sections 13, 14, 15, 16: All; Sections 21, 22, 23, 24: All; Sections 25, 26, 27, 28: All; Sections 32, 33, 34, 35, 36: All.

#### Garfield County

T.31S., R.1W., S.L.B.& M.

Section 1: All.

#### Wayne County

T.30S.,R.1E., S.L.B.& M.

Sections 5, 6, 7, 8: All; Sections 17, 18, 19, 20: All; Sections 29, 30, 31, 32: All.

#### Garfield County

T.31S., R.1E., S.L.B.& M.

Section 5: Lots 4, 5, 12, W<sup>1</sup><sub>2</sub>SW<sup>1</sup><sub>4</sub>;

Section 6: All.

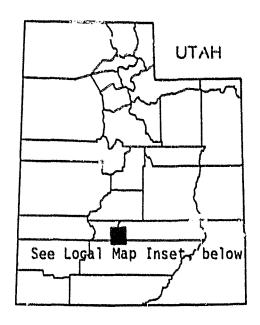
Approximately 71% of the state land block lies in Piute County, 25% is in Wayne County, and 4% is in Garfield County. Figures la and lb indicate the location of the study area within the state.

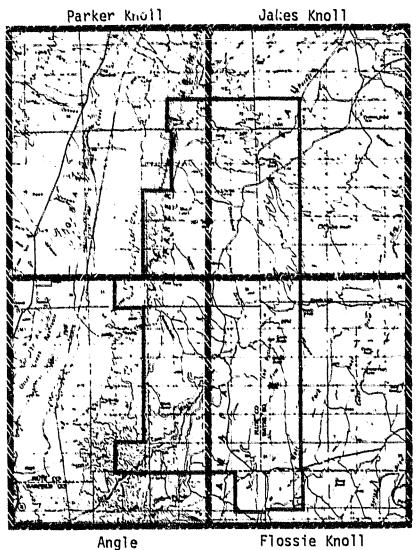
The Parker Mountain study area primarily consists of rolling sagebrush-covered hills, which surround islands of aspen forests. Big sagebrush and aspen dominate the western half of the study area, while the eastern half is characterized by black sagebrush with big sagebrush areas in swales and on north and east facing slopes.

The study area lies on the western edge of the Awapa Plateau, which is an eastward sloping plateau covered with various types of volcanic flows and deposits. The western edge of the plateau ends abruptly with the escarpment of the Paunsaugunt Fault. Generally, elevation in the study area ranges from 9.800 feet on the western rim to 8,600 feet on the east, but portions of the study area lying to the west of the plateau are as low as 7,200 feet. The climate is

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Figure la. Regional location map showing the area covered by the four U.S.G.S. quadrangles shown in the local map inset.





Flossie Knoll

Figure 1b. Local map inset to the regional map showing the four U.S.G.S. topographic quadrangles which cover the study area. The Parker Mountain State Land Block is outlined with solid bold lines.

characterized by cold, snowy winters and warm summers. Nearly 60% of the annual 16-20 inches of precipitation comes during the dormant season, and the remainder falls as rain usually in the late summer months. The soils in the area are generally loamy, rocky, and well drained. There is little surface water in the area except where ponds or reservoirs have been constructed to capture melting snow runoff.

Figure 2 illustrates the area within the state land block which is the primary focus of this study. The state land block is surrounded on the north, east, and south by a barbed-wire fence. Likewise, north-south and east-west division fences within the plateau portion of the study area have created seven pastures. The western edge escarpment and canyon rim of Dry Wash are natural barriers to livestock movement. Areas within the state land block of greater than 40% have received little attention in this study. Such areas are relatively inaccessible and/or fragile and are unlikely to receive intensive management. Although most of Dry Wash has steep slopes, a relatively gentle portion near the bottom of Dry Wash comprises an eighth pasture.

Parker Mountain supports a diversity of game and non-game wildlife. A large number of antelope spend the summer in the eastern portion of the land block. Sage grouse are also abundant in the area. Deer and elk may be found on the western rim during the summer. Prairie dogs, golden eagles, rockchucks, and other non-game wildlife species are frequently observed in the study area.

#### <u>Historical Background</u>

Records in the Bureau of Land Management's Utah Land Office indicate that the State of Utah initiated its ownership interest in Parker Mountain between 1917 and 1924, when the area was surveyed.

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Figure 2. Outline of pastures inventoried in the study area. Also shown are the locations of sources of water.

# Red Knoll Parker Hollow Parker Knoll Parker Lake **Nicks Buttes** South Dry Wash

#### PASTURE\*/WATER MAP LEGEND

+++ Fence

- Pond/reservoir/troughs
- •••• Abrupt break in slope
- ---- Break in slope
- ---- Interface between upper and lower reaches of Dry Wash

\*Portions of the study area not included within pasture units are considered to be relatively inaccessible to livestock.

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Title to the school sections (i.e., Sections 2, 16, 32, and 36) which make up approximately 17% of the area, passed at the time of survey. Between 1943 and 1950, the state acquired an additional 76% of what presently constitutes the study area through indemnity list selections: lands selected in lieu of numbered school sections elsewhere, title to which could not pass to the state primarily because such sections had been withdrawn or appropriated from the public domain prior to survey. In 1958, the state received a patent to the surface of an additional 4% of the study area; the federal government retained ownership of minerals in the following land: All of Section 3, and SigNWia, SWia of Section 13, T.29S., R.1W.; all of Section 29, T.29S., R.1E.; and lots 4, 5, 12, and WisSWix of Section 5, T.31S.,R.1E. State ownership of the land block was completed in 1967, when Sections 34 and 35, T.28S.,R.lW., were received via state exchange patent. Presently, land owned by the Bureau of Land Management ("B.L.M.") borders the land block on the north, east, and west, and land owned by the Forest Service borders to the south.

After acquiring substantial land holdings on Parker Mountain by 1945, the State Land Board issued a 10-year grazing lease to the B.L.M. (Division of State Lands and Forestry 1982). Prior to this time, open grazing had been allowed on Parker Mountain without regard to plant and soil conditions. The area was being used principally as summer range by sheep, and adjacent B.L.M. land was being used for spring and fall grazing. During the course of the grazing lease to B.L.M., some sheep permits were converted to cattle permits. Approximately 1,100 cattle were permitted to graze during the summer months, and 1,100 sheep grazed the range during the summer beginning July 1 and ending October 15. Approximately 1,700 sheep used the range from May 15 to July 1 for

spring grazing and lambing. Many cattle also utilized the range during the spring. At that time, there were no fences in the area and there were only two sources of open water: Forshea Spring and Chicken Spring. In 1956, the Division of State Lands resumed management of the area. Management continued as usual until the Division of State Lands, the Soil Conservation Service ("S.C.S."), and the grazing permittees began to plan alternative grazing strategies in 1960.

By 1960, the grazing practices of prior years had left the grazing resources on Parker Mountain in extremely poor condition. There had been little enforcement of the grazing permits' limits on livestock numbers, and seasons of grazing. In some instances, cattle left the range in the fall in such poor condition that they had to be hauled from the area (Andrews 1982). Calf gains continually decreased as the range was depleted of usable forage, and cattle had to be moved from the area six to eight weeks after turning them into the area. The fact that water had to be hauled to the land block added an additional burden to grazing management. Overutilization of the range for an extended number of years had produced a number of areas where soil movement from wind and water erosion was evident. Hardly any desirable grass species in the sagebrush-dominated areas were to be found on Parker Mountain, particularly near water sources, and some species formerly in the area were absent. Heavy grazing in aspen understories had practically eliminated aspen reproduction and many desirable herbaceous forage species.

In 1959 the Division initiated action which would begin a program to reverse the trend of deterioration on Parker Mountain; it entered into an agreement with the B.L.M. to share the cost of a barbed-wire

fence to extend along the north and east borders of the land block. In 1960, the S.C.S. met with the 42 Parker Mountain permittees: two-thirds of which were running cattle; with the remainder running sheep. It was established that 1,109 cattle would begin grazing on the block June 1, and 1,181 sheep would begin grazing July 1. All livestock would leave the block on October 15 of each year. The S.C.S. worked with the permittees to establish a range conservation plan which continues to provide the foundation for grazing management on the block. Available forage at that time was estimated to provide 5,700 animal units months ("A.U.M.").

Under the 1961 range conservation plan, range improvements to increase livestock carrying capacity without reducing the number of animals permitted included rotation-deferred grazing, brush spraying, reseeding, fencing, and water developments. The plan initially called for the creation of four pastures on the block by constructing three east-west cross fences. This was to have allowed the creation of a rotation-deferred grazing system; each year livestock would initially be turned into a different pasture for approximately one month before moving them to other pastures. However, by the early 1970's, no pasture fences had been completed.

Initial range improvement efforts were focused on water developments and sagebrush spraying. By the mid-1960's, over 5,000 acres of big sagebrush in what are now the Parker Hollow, Parker Knoll, and Nicks pastures were sprayed, but not reseeded; the plan was to allow remnant understory plants to be released by destroying the sagebrush. Spraying in the Parker Hollow pasture produced a good kill of sagebrush. Understory grasses responded well and even today, in many areas in this pasture, sagebrush is having difficulty competing with grass species.

Sagebrush eradication efforts in the Parker Knoll and Nicks areas were not as successful. Spraying in the Parker Knoll area produced a good kill of sagebrush but, since there were drought conditions that year, cattle were allowed to graze the area before it was ready and sagebrush is presently dominating the area. The spraying efforts in Nicks pasture did not produce a good kill of sagebrush.

By the mid-1960's, over 20 water developments had been completed which permitted better distribution of livestock and better utilization of forage. Many of the water developments are small reservoirs which are filled by melting snow. Such improvements led to an increase of available A.U.M.'s to 6,392, and the number of cattle permits was increased to 1,138 cattle plus calves, and 1,270 sheep plus lambs.

During the early and mid-1970's, division fencing was completed to create seven major pastures on the Awapa Plateau. An eighth pasture lies in Dry Wash and is somewhat isolated from the rest of the block pastures by steep slopes. The seven major pastures were set up to operate under two cycles of rotation-deferred grazing. The four northern pastures form one group, where livestock begin the grazing season in either Red Knoll or Parker Lake pasture, and later move to the western pastures. In the south, livestock alternate between the Buttes and South pastures before moving into the Micks pasture.

Although the management of range resources on Parker Mountain has fallen short of the 1961 range conservation plan, steady progress has been made. Desirable grass species such as bluebunch wheatgrass and sheep fescue are now quite common. The most recent improvement efforts have included additional water developments and prescribed burning of big sagebrush patches in Red Knoll and Parker Lake pastures. Range

recovery has been slowed because there have not been any significan efforts to reseed in the area. Although some broadcast seeding of smooth brome and orchard grass under aspen before leaf fall produced encouraging results, grazing pressure has prevented permanent establishment of significant herbaceous understories under most aspen stands. The rotation-deferred grazing system appears to be producing desirable results, but there continues to be a significant amount of livestock trespass in the Nicks and South pastures from animals turned into Dry Wash too early in the season. Dry Wash is technically part of the overall Parker Mountain grazing system, but receives little management and tends to be grazed in the early spring as well as late fall.

The land block is presently managed to provide 6,400 A.U.M.'s of summer forage. The grazing lease for such forage resources is held by the Parker Mountain Grazers Association. That lease was initiated January 1, 1974 and will expire December 31, 1989. The annual rental for the lease is \$3,285.40, or approximately \$.50 per A.U.M.

The Parker Mountain State Land Block supports over 5,700 acres of aspen forests, with some aspen-conifer forest mix included. The Division of State Lands and Forestry prepared a timber management plan in 1981 for Parker Mountain, in which 35% of the aspen was determined to be merchantable. It should be noted, however, that such plan assumed an aspen forest resource which covered 4,300 acres. The merchantable timber (i.e., trees ten inches in diameter and larger) volume has been estimated to be over 5 million board feet (mbf), with the following breakdown of risk categories: 2 mbf low risk, mature trees with minimum rot or other defect; 1 mbf medium risk, mature or overmature trees with some rot or other defect; and 2 mbf high risk, overmature trees with considerable

defect of both decay and form. Approximately 32% of the aspen stands are unmerchantable because of very poor access and they do not have merchantable size aspen. Trees with a diameter of less than nine inches, or poles and saplings, make up 28% of the aspen acreage. The remaining 5% forest area on the land block is made up of aspen-conifer mixes. It has been estimated in the timber management plan that aspen on Parker Mountain reach maturity at 90 to 120 years. The management plan calls for clear cut harvesting, when trees reach 40 to 45 feet in height, on a 105 year rotation. Management of aspen, to avoid loss of excessive volumes of timber to disease and decay, must be intensive and be initiated very soon. The high risk stands should be removed within the next five years, the medium risk stands should be removed within the next 15 years, and the low risk stands should be harvested within the next 40 years. Harvest of aspen on Parker Mountain can be managed to produce minimal erosion and will enhance the rejuvenation of aspen and aspen understories, especially if reseeding of herbaceous species is included. Unfortunately, market demand for aspen timber has been sufficiently low to prevent effective implementation of timber management on Parker Mountain.

Parker Mountain presently supports a great diversity and abundance of wildlife, a condition which has not always been the case for some species. The land block makes up approximately 20% of the range occupied by the state's largest antelope herd. The antelope herd unit includes the entire Awapa Plateau, but a large portion of the estimated 1,200 head herd summers on the state land block. This herd unit now provides for an annual buck harvest of nearly 100 head, and typically up to several hundred antelope are transplanted from the herd to other

areas in the state each year. Although it is difficult to estimate the antelope herd population for 50 to 100 years ago, overgrazing of forage resources contributed toward the dwindling of herd numbers, which ended in the herd's demise in the hard winter of 1948-49. After that time, no antelope could be found in the area until a total of 130 antelope were cransplanted to the herd unit in 1964 and 1965. Since the time antelope were reintroduced, the herd has had steady annual growth.

Other big game on the land block include a few elk and probably several dozen mule deer which summer along the western edge of the area. Quite likely, their presence on the block represents a natural reintroduction after previous deterioration of habitat conditions.

Prairie dogs continue to maintain a noticeable niche on Parker Mountain. Prairie dog mounds, both occupied and abandoned, have the effect of enhancing soil moisture holding capacity which results in islands of larger and more abundant vegetation than in surrounding interspaces. Such mounds dot the landscape, although prairie dog populations are presently restricted to four locations in the study area. A 1982 spring survey of adult prairie dogs led to the following estimations of animal numbers at the sites indicated: 63, Forshea Draw; 52, Flossie Lake; 12, Dog Lake; and 4 (a significant decline from prior years' surveys), Cedar Draw. The prairie dogs on the state land block make up over one-half of the 1982 spring survey of 218 for the combined state and B.L.M. area on and around Parker Mountain. The Parker Mountain populations are a significant portion of the 1982 population estimate of 363 prairie dogs in naturally occuring colonies on public lands in Utah. The bulk of the prairie dog population in Utah occurs

on private land, but private landowners are unlikely to provide nearly as much protection to this endangered species as state and federal agencies. As part of the Utah Prairie Dog Recovery Plan, the Division of Wildlife Resources is presently seeking to establish prairie dog colonies near Mud Lake and Parker Lake in the study area. Although competition between prairie dogs and livestock is miniscule (i.e., estimated 300-400 prairie dogs per animal unit equivalent for calculating A.U.M.'s), it is likely that prairie dog populations and range were affected by overgrazing and deteriorated forage conditions of the past.

Parker Mountain continues to provide excellent summer and fall habitat for sage grouse. Although a historical analysis of the sage grouse population is not available, it appears that sage grouse have had ample habitat for sometime and that sage grouse hunting in the area is good (Jarvis 1970, 1971).

Parker Mountain is of little hydrologic consequence to the two major drainage basins with which it is associated. Approximately two-thirds of the study area drains to the east, and is hydraulically linked to the Fremont River. However, most surface water originating on Parker Mountain feeds into water storage reservoirs, and the remainder flows into either ephemeral or intermittent low gradient drainage channels which wind across the Awapa Plateau. It is unlikely that surface water from Parker Mountain ever completes the journey to the Fremont River. (See Utah Division of Water Resources 1977.) The remaining one-third of the study area drains into the Upper Sevier River Basin either through Forshea Draw and Dry Wash, or from the western slopes of the study area. Again, these drainage channels are presently ephemeral or intermittent, and it is unlikely that surface

water contributes significantly to the Sevier River. There is a greater probability that ground water from the study area contributes to the flow of major rivers in the area, but it is unlikely that management of surface resources on Parker Mountain has a significant impact on such contributions.

Although it has been assumed in this study that the long-term management emphasis on Parker Mountain is for renewable resources, it is interesting to note that short-term development of non-renewable resources offers significant economic potential. In September 1981, nearly all of the study area was leasled to various individuals and companies for the development of oil and gas resources. The remainder of the area was either already under state lease or is under B.L.M. mineral lease. First year competitive bid payments for the 1981 leases exceeded \$867,000 (ca. \$20 per acre), and annual rental for the ten-year oil and gas leases is \$1 per acre. This presents quite a contrast to the annual rental of approximately \$0.07 per acre for the current grazing lease. Although seismic exploration crews have been active in the area since 1981, there has been no drilling in the area and it is not known whether drilling is likely to occur.

This historical review has focused on significant aspects of Parker Mountain state-owned resources for which information has been available. The area certainly is endowed with a variety of resources with both economic and esthetic value. Future management of Parker Mountain is very likely to focus greater attention on multiple use management goals than was done in the past. Such an orientation could include the possibility of private or public recreation development on portions of the area.

#### MET'HODS

#### Aerial Photo Interpretation

The primary medium for analysis and mapping was high-altitude color infrared aerial photography flown for the B.L.M. on July 1-2, 1975. The photography is good quality and is nearly cloud-free. Film positive transparencies at a scale of approximately 1:31,680 were utilized. Conventional black and white photography, at a scale of 1:40,000, but enlarged to 1:24,000, was also obtained. This black and white photography was flown on October 4, 1978.

The first stage of map production was to interpret the mapping units: areas that appear homogeneous within each unit and have contrasting visual properties which may be detected on the photographs. Mapping units were identified by examining the following: the color, texture, and patterns on the photographs; hydrologic features; topography; and ecological context. An initial visit to the study area in June 1982 was made before significant mapping was commenced.

The next stage of production was to delineate aerial photograph mapping units at the final map scale, which is 1:24,000, correct for photographic displacement, and register interpretations with the standard 7½ minute U.S.G.S. quadrangle base. This step was accomplished, for mapping units with readily discernable boundaries, through the use of U.S.G.S. orthophoto quadrangles. Mapping of units with relatively subtle border contrasts was assisted with the use of a K&E Kargl cartographic projector, an enlarging light table; this technique allows the user to project the photograph or overlay onto a base map to make adjustments. The mapping units were then labeled with initial interpretations of vegetation cover.

After interpretations were enlarged to the U.S.G.S. quad scale, a second two-day trip to the study area was made in September to verify the draft interpretations and delineations.

Field checking the interpreted patterns was facilitated by the accessibility of most of the study area. Numerous dirt roads and trails throughout the area permit adequate access, especially in a four-wheel drive vehicle with good ground clearance. Generally, field notes were made on the 1:24,000 black and white aerial photographs, and later transferred to the draft vegetation map. A Landsat digital print map overlay, which is discussed below, assisted in labeling areas which were inaccessible, or which were not field checked.

The mapping process also involved the delineation of portions of the study area which are relatively steep. Topographic map contour lines and analysis of stereo photography permitted the delineation of an approximate interface between major pasture units and areas with slopes that generally exceed 40%. Such breaks in slope indicate the beginning of terrain which is relatively inaccessible to livestock.

The draft vegetation cover map delineations and interpretations were refined in the laboratory after the second field trip. A two-day field trip was then taken in October to verify and make final refinements of the map. Acreage determinations were then made using an area measurement computer program and digitizing tablet.

#### <u>Landsat Digital Data Analysis</u>

The analysis and mapping performed in this study were accomplished at the facilities of the Center for Remote Sensing and Cartography, using digital data obtained from NASA's Landsat II satellite. The data necessary for the study, a computer compatible tape (CCT) recorded

July 28, 1979, was already available at the Center. For data processing, the Center was able to utilize the "ELAS" package of computer software routines, developed by NASA's Earth Resources Laboratory in Missouri, which is operational on the University of Utah Research Institute's PRIME computer.

A brief explanation of the nature of the data contained on CCT's follows. Each Landsat scene represents a huge matrix of individual cells called picture elements or "pixels," for which light radiance values are recorded. Each scene contains over ten million pixels; each pixel represents an area which is approximately 56m by 79m (ca. 1.1 acre). The satellite's multispectral scanner (MSS) records light reflectance values for the combined land cover or terrain features contained within each pixel. Reflectance values for four light spectral bands, two in the visible and two in the non-visible near infrared portions of the electromagnetic spectrum, are electronically relayed to earth receiving stations. The wavelengths corresponding to each band are as follows:

Band 4 (green light) 500-600 nanometers (10<sup>-9</sup>);
Band 5 (red light) 600-700 nanometers;
Band 6 (near infrared) 700-800 nanometers;
Band 7 (near infrared) 800-1100 nanometers.

The digital processing of Landsat data is performed to use MSS values for each pixel in classifying pixels of similar spectral characteristics into groups or classes, which can then be correlated with field data or "ground truth." The primary rationale for performing digital processing of MSS data has been stated by Hutchinson (1982), as follows:

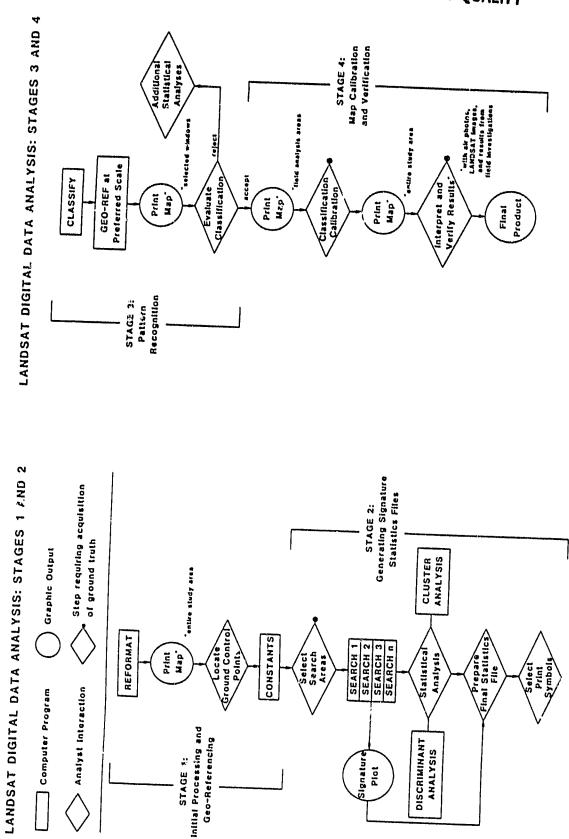
"The argument made for digital multispectral classification is that, when considering the spectrum as a whole, different objectives have different patterns of reflection and emission. Further, it is assumed that these spectral patterns are sufficiently unique to make objectives consistently distinguishable from one another using statistical classification techniques."

Although Landsat is a relatively inexpensive means of analyzing and inventorying large areas of vegetation resources, variability of objects within a single multispectral classification may be quite high (Todd, et al. 1980). For this reason, efforts to increase resolution, and, more importantly, efforts to use ancillary data (e.g., digital topographic data) to improve classifications are being performed (Tom and Miller 1980).

Raw Landsat data must first be reformatted to make them compatible with processing hardware. Next, the digital data are or graphically corrected to remove the effects of earth curvature, sp :. (See Stage 1 of Figure 3.) Thereafter, a program called "SEARCH" is usuazed to generate statistics which characterize pixel groups having similar spectral features across the four bands. (See Stage 2 of Figure 3.) SEARCH is a routine which is used to provide training statistics for a program called "MAXL," which classifies individual pixels into groups based upon each pixel's highest statistical probability of belonging to a given group. Generally, a Landsat researcher selects several blocks of data or "windows" within the Landsat scene for the purpose of finding representative spectral signatures for range cover classification in the study area; areas thus selected are known to contain the forest, range, wetland, or other cover types of interest. However, in this study the entire study area was used as the window.

Once the study windows are selected, the program SEARCH examines each contiguous six scan line (Landsat pixel matrix "row") by six element block (pixel matrix "column"); if the spectral data within the six by six block are too heterogeneous, the program will switch to the use of a three by three block of pixels. The statistics generated by SEARCH include mean pixel light reflectance values for each of the four bands, a covariance matrix, and a priori values. A set of statistics is generated by SEARCH representing various classes of light reflectance patterns found in the study area "searched." The four mean light reflectance values, one for each MSS band, are plotted to form a curve called a "light signature" which characterizes each class. SEARCH thus "trains" MAXL to recognize different ground cover patterns as it places individual pixels into classes. A knowledge of the manner in which different land cover features form spectral signatures, combined with the analysis of aerial photography and field checking of digital classifications, allows remote sensing recarchers to provide an interpretation of Landsat-derived classes.

In this study, the SEARCH program produced forty-six signatures; further efforts were directed toward finding those signatures which would most likely reflect the major types of rangeland habitat on the plateau portion of the study area. Stage 2 of Figure 3 illustrates several of the steps utilized in making detailed studies of signatures. The signature plot, described above, permits a substantial amount of interpretation; spectral signature shape and magnitude of reflectance are diagnostic of land cover types. Generally, similarly shaped signature curves indicate similar cover types while upward or downward shifts of similar curves indicate differences in topography or amount of ground cover.



Summary of the steps in Landsat digital data analysis. Figure 3.

Spectral signatures are also studied statistically to detect similarities and differences. First, a principal components analysis of the mean values for each signature's four MSS bands reduces such data to factor scores for two components; typically bands 4 and 5 are combined into one component ("visible" light), and bands 6 and 7 combine to form the second ("infrared" light). Next, the factor scores are used in a cluster analysis which groups spectral signatures according to a similarity index. Finally, the factor scores and group clusters are used in a discriminant analysis of the signatures. The two-dimensional scatter plot produced in the discriminant analysis allows one to receive a graphical view of signature relationships; the discriminant analysis scatter plot, with two axes representing the visible and infrared light components, may be divided into regions or groups of signatures that correspond to similar ground cover types. This process is a vital link in allowing an often unmanageable number of signatures to be combined into groups of similar signatures. This procedure allows the researcher a great deal of flexibility in performing Landsat digital analysis; a large number of signatures are available and one may concentrate on the signatures of particular interest, while signatures of lesser interest may be grouped together or omitted. The use of discriminant analysis, based on MSS principal components and cluster analyses, in combination with examination of spectral signature plots and field experience has been a key element in achieving good results from the unsupervised approach to Landsat data analysis. Such analyses were performed for the signatures in this study and will be discussed below.

A second approach to the analysis of Landsat data was also explored.

Reformatted Landsat data were spatially "filtered" to increase homogeneity

of pixel spectral values within a given cover type. In general, data filtering involves adjusting raw spectral values for a given pixel to reflect the average spectral reflectance of a three by three pixel matrix around that pixel. This process tends to smooth out subtle spectral differences within an area which often results in the enhancement of edges between areas that have significant spectral differences. However, in this study, the initial comparison of Landsat maps from both filtered and non-filtered data demonstrated that the map from filtered data included an unacceptable amount of spatial smoothing. That is, a number of vegetation boundaries which are of management significance were generalized to too great an extent. It became apparent that the spatial complexity of the area, in addition to the often subtle spectral differences among land cover types, suggests that non-filtered data should be used in this study.

An additional and most vital dimension to the process of digital data analysis is calibrating spectral signatures with "ground truth." This is accomplished by assigning print symbols to each signature or signature group and printing maps which may then be registered to standard base maps or referenced to photographs and field study sites. In this study, a digital print map overlay was prepared to match the U.S.G.S. 7½ minute quadrangles (scale 1:24,000) mosaic of the study area. Calibration of spectral signatures with actual land cover types was accomplished primarily by use of the vegetation map prepared from photo interpretation, high altitude color infrared photography, and field observations. The above-described process of interpreting and combining spectral signatures based upon signature curve similarity, discriminant analysis of the signatures and calibration of signature print symbols with photograph and ground observations is outlined in Stages 2, 3, and 4 of Figure 3.

The digital map calibration process indicated substantial spectral similarity, and therefore confusion, between sites dominated by a relatively low growth form of big sagebrush and black sagebrush. This spectral similarity is not surprising considering that both shrubs occupy similar ecological sites: generally on south and west facing slopes which are rocky and relatively dry. Such differences are also not evident on color infrared photography, but must be ascertained in the field. However, black sagebrush appears to occupy this ecological site only on the western rim of the plateau and in areas to the east of a generalized 8,250 feet elevation contour. To improve the digital classification, the zone occupied by the short growth form of big sagebrush was digitized and an algorithm constructed to allow the detection of differences between sagebrush species. Basically, the algorithm assigned each pixel with spectral signatures common to both species to different classes depending upon the location of the pixel with respect to the digitized zones.

Other areas of spectral similarity were also addressed by the introduction of ancillary data. The surface geology of eastern half of the study area is predominantly older volcanic material in the north, with the exception of Red Knoll, and very recent volcanic flows in the south. The topography in the north is characterized by a series of smooth ridges running in a southeast direction, whereas the southern area has more of a plateau character with various exposures. The combination of surface geology and topography differences between the areas has resulted in the confusion of big sagebrush, which grows in swales and northeast exposures in the north, with the black sagebrush signature of the south; since the black sagebrush areas which occur on southwest slopes in the north are spectrally different from black sage-

brush on the recent volcanic flows in the south, there is little confusion between this spectral class and big sagebrush classes. The recent volcanic flows were digitized as separate units within the study area and new Landsat spectral class numbers were assigned to the signatures causing the confusion. Similar spectral likenesses were enountered in the Dry Wash pasture and was dealt with in a similar manner.

Spectral similarity was also encountered in areas which are primarily bottomland loamy soils with mountain silver sagebrush or wetland vegetation cover. The majority of bottomland soils were digitized from an available S.C.S. soils map and spectral signatures not normally associated with mountain silver sagebrush and wetlands were reassigned class numbers to avoid confusion.

#### RESULTS AND DISCUSSION

#### Inventory from Photo Interpretation

The primary final product of this study is the 1:24,000 rangeland cover map overlay, a folded translucent paper copy of which is attached as Appendix A. This paper copy may also be used as a diazo master for the preparation of duplicate copies. The map overlay is designed to register to a map mosaic of corresponding U.S.G.S. topographic quadrangles or orthophoto quadrangles. If the user places the map on topographic quads, wooded areas correspond closely to green patches on the topographic quads. Map users should note that the eastern quads (Jakes Knoll and Flossie Knoll) have 20 feet contour intervals, whereas the western quads (Parker Knoll and Angle) have 40 feet contours. Unlike topographic quadrangles, orthophoto quadrangles for the study area are not available at the various map outlets in Utah but may be ordered from the following:

National Cartographic Information Center Federal Center, Box 25046, Stop 504 Denver, CO 80225 Phone 303-234-2326

As mentioned above, the vegetation map overlay was prepared primarily from the analysis of color infrared (CIR) photographs, augmented with field observations from several short visits to the study area. High altitude CIR photography proved to be an ideal photographic medium for the task of mapping rangeland resources; it provides high resolution prints with more information and less displacement than low altitude photographs, and is relatively unaffected by atmospheric haze which significantly scatters blue light. In addition, contrasts between different vegetation types such as aspen and sagebrush are extremely

vivid, whereas black and white photography often obscures such boundaries. CIR photography also generally produces greater discrimination between vegetation types than natural color photography because infrared light reflectance is highly sensitive to plant leaf shape and cell differences, as well as plant vigor.

Despite the advantages offered by the CIR photography in this study, field observations and ecological interpretations were vital in completing the mapping process. Generally, different ground cover types were found to be associated with distinct patterns of color, tone, and texture on the CIR photographs. A few circumstances led to confusion in interpreting the photos. In the north eastern quarter of the study area, black sagebrush occupies ridgetops and south facing slopes. The same ecological sites in the western portion of the study area are occupied by a short growth form of big sagebrush. Black sagebrush also occupies west-facing slopes on the western rim of the study area. The east-west transition of one species to the other is not detectable from the photographs, but was mapped to reflect field observations. That is, an observation at one point would indicate big sagebrush, an observation at a second point would indicate black sagebrush. Since the precise location of the transition zone between the two could not be seen from the photographs, it was approximated from the results of all field observations.

Another source of confusion came from areas with black sagebrush and big sagebrush growing on basalt flows. Reddish-brown basalt rocks on the soil surface often form a dominant feature in such areas that tends to produce a CIR photo color-tone pattern, making the two vegetation types indistinguishable. Examples of such problem areas are around Red

Knoll and near the eastern rim of Dry Wash. Field observations helped to sort out the confusion. However, the delineation between big sagebrush and black sagebrush near the upper reaches of Dry Wash can only be considered an approximate boundary based upon limited field observations.

In addition to field observations, a number of other sources of information aided in photo interpretation efforts. The Landsat digital map often flagged areas which might otherwise have gone unnoticed because of subtle visual differences. Available geology, soils, precipitation, and topographic maps were also quite helpful. The presence of prairie dog mounds was also quite useful in making interpretations: the mounds support big sagebrush (tall growth form) and green rabbitbrush shrubs which make them stand out as islands on black sagebrush areas or areas supporting the short growth form of big sagebrush.

The map legend in Appendix A describes several important boundaries. The boundary of the state land block is shown with a solid bold line, and barbed wire fences are depicted by a series of "+" symbols. The perimeter fenceline generally conforms to the state land boundary except for a few jogs along the east boundary which include approximately 80 acres of B.L.M. land within state range pastures. Along the western edge of the Awapa Plateau and along the canyon rim of Dry Wash a series of heavy dots depicts an abrupt break in slope. This break in slope is often a rocky cliff, but may also be a milder transition from the gentle slopes of the plateau to slopes steeper than 40%. This abrupt break in slope has been treated as a fenceline for purposes of pasture delineation in this study. However, the break in slope is of little significance to wildlife movement off of the Awapa Plateau, and is not completely effective with regard to livestock (i.e., it has been reported that some livestock make

their way up the sides of Dry Wash to the Buttes and Nicks pastures in the spring). Less than "abrupt" transitions to areas with greater than 40% slope have not been mapped per se, but map symbols accompanied by an apostrophe indicate areas where average land slope exceeds 40%, and therefore may be less accessible to livestock (at least cattle).

Vegetation boundaries are depicted in Appendix A by solid lines.

The minimum mapping unit for most cover types was several acres. The mapping of aspen included units which are sometimes less than one acre because of the distinctiveness of the cover on the photography and, perhaps, management importance. The areal polygons mapped may be considered to have relatively homogeneous land cover. However, this determination of homogeneity is a compromise. It would be possible, albeit more difficult, to delineate different types of aspen forest, various degrees of sagebrush vegetation mixing, or sagebrush/soils categories. In addition to adding new classes to the map legend, smaller polygons of the vegetation classes mapped could have been delineated. The map legend and manner of delineating polygons, which have produced Appendix A, represent a compromise between mapping as much information as is possible from the photography and preparing a visually interpretable map where patterns may be detected.

The map overlay is intended to facilitate the inventory of rangeland resources (i.e., acreage calculations) as well as photo interpretation of the CIR photos used to prepare the map. It is expected that detailed management of Parker Mountain should include the use of a set of CIR photography. For example, the location of field transects for monitoring of condition and trend should be within areas that appear homogeneous on the photographs. Merely assuming homogeneity within map polygons could

lead to locating transects across land cover boundaries which are too subtle or too small to have been mapped, but which could lead to serious errors in field sampling. Also, one might erroneously select a field study site based on a map polygon which is internally homogeneous but which may not be "typical" of that vegetation type within the pasture unit; the manager should select an area which is in an area on the photo which typifies that vegetation type in terms of color, tone, and texture. As will be noted below, the Landsat map is an additional source of information intended to assist in the location of field monitoring stations.

The legend in Appendix A indicates that eight major rangeland cover types have been mapped. An expanded description based upon general field observations follows (scientific names for associated species are given in Appendix E):

- 1. Black sagebrush (Artemisia nova). Occurs on west-facing slopes of the western rim of the plateau, on southwest slopes in the northeastern quarter, on various slopes on basalt flows and volcanic sediments in the southeastern quarter, and on unprotected exposures in the Dry Wash pasture. Major associated species include sheep fescue, letterman needlegrass, squirreltail, and forbs such as mat-forming pusseytoes, Indian paintbrush, cinquefoil, and phlox. Abandoned prairie dog mounds are common in some areas which form small islands (ca. 5-10 meters in diameter) dominated by big sagebrush and green (or "desert") rabbitbrush. Surface cover is 40-50% shrub, 30-50% rock/bare soil, less than 20% grass/forb, and less than 10% litter.
- 2. Mountain big sagebrush: tall growth form (Artemisia tridentata ssp. vaseyana). Occurs generally on protected exposures and bottoms in the western half of the study area and on northeast slopes in the eastern half. Major associated species include needle-and-thread grass, letterman needlegrass, junegrass, Sandberg bluegrass, squirreltail, with lupine, and a variety of other forbs. Surface cover is 20-50% shrub, less than 30% rock/bare soil, 10-40% grass/forb, and less than 10% litter. Areas on the map with the symbol "#" contain a significant grass understory in the vicinity. Such areas often have a very loamy surface soil appearance.

- 3. Mountain big sagebrush: short growth form (Artemisia tridentata ssp. vaseyana). Occurs on southwest slopes in northwestern portion of study area and on various exposures in southwestern portion. Also often forms an unmapped transition zone between tall form mountain big sagebrush and black sagebrush. Major associated species include those mentioned above for black sagebrush and tall form mountain big sagebrush. Cover components are similar to black sagebrush areas. Abandoned prairie dog mounds, as described for the black sagebrush areas, often create an island/interspace appearance to this community.
- 4. Mountain silver sagebrush (Artemisia cana ssp. viscidula).

  Occurs in major drainage bottoms with deep loamy soil. Water table depth is probably near the surface at least during part of the season. The major associated species is dryland sedge. Surface cover appears to be approximately 30-50% shrubs, 10-20% grass/forb, 20-40% bare soil, and less than 10% litter.
- 5. Wetland (Juncus/Carex). Occurs primarily around Parker Lake, Forshea Reservoir, Dog Lake, and Mud Lake. With the exception of Forshea Reservoir, this type is dominated by rushes, with associated sedges and forbs (primarily Helianthella uniflora). The Forshea Reservoir area is predominately sedge. Ground cover is nearly continuous vegetation. Water table is near or at surface most of season.
- 6. Aspen (Populus tremuloides). Occurs usually in protected pockets throughout study area but mostly in the western half. This type includes a variety of tree heights, densities, and levels of apparent vigor. Generally, tree health appears fair to good and most forests appear mature or overmature. Some mature forest areas have prolific suckering at the present time (e.g., in northwest area near Dog Lake). Some aspen areas have sagebrush understories but most, generally the larger forests, probably had a productive herbaceous understory prior to intensive grazing but presently have hardly any understory.
- 7. <u>Douglas fir (Pseudotsuga menziesii)</u>. Occurs with other conifers on protected slopes in Dry Wash and along the western rim. This constitutes a very minor vegetation type in the study area. Scattered conifers mix in with aspen but no assessment of probabilities and rates of succession from aspen to conifer has been made.
- 8. <u>Pinyon-juniper</u> (<u>Pinus edulis</u>, and <u>Juniperus osteosperma</u>). Occurs exclusively in Dry Wash. A minor cover type in terms of areal extent.

The delineation of the vegetation cover types noted above provides an indication of present forage composition, but, more importantly, it provides a primary means of assessing site potential. The plant

community occupying a given site is a "synthometer" of the total environment of that site. The biotic and abiotic components have, over time, led to the dominance of the existing vegetation. Since Parker Mountain has not recently had any widespread major disturbances, it has been assumed that the vegetation types mapped in Appendix A and on the Landsat map indicate distinct sites for which management prescriptions may be developed. This is especially the case when the vegetation information is combined with other maps depicting soils, geology, and precipitation characteristics. This aspect of the study will be explored in the next section.

Aspen may often be an exception to the general observations regarding the site indicator value of species made above. Genetically controlled clone variations on what appear to be similar sites was observed on the photography and in the field. Consequently, extrapolation from present aspen forest condition to site potential becomes complicated, when possible.

Range managers have found that looking closely at sagebrush taxonomy yields valuable information about range resource potential (Winward 1982). Of the sixteen described taxa of woody sagebrushes in Utah, three have been mapped on Parker Mountain. The identification of mountain silver sagebrush and black sagebrush is fairly straightforward, even though evidence of hybridization between black sagebrush and big sagebrush was observed in the field. It should be noted that although fringed sage (Artemisia frigida) and low sage (Artemisia arbuscula) occur in the study area, they were not found in stands of mappable size.

In light of a growing literature on big sagebrush, it has become increasingly important to identify big sagebrush on a subspecies level in performing resource inventories. Three subspecies of big sagebrush have

been extensively described in the literature: mountain big sagebrush, ssp. vaseyana; basin big sagebrush, ssp. tridentata; Wyoming big sagebrush, ssp. wyomingensis. The reader is referred to the following sources for excellent treatments of subspecies distinguishing characteristics: Winward 1982; McArthur 1982; Blaisdell, et al. 1982; Winward and Tisdale 1977: McArthur, et al. 1979; and Winward 1980. Generally, examination of Parker Mountain big sagebrush in the field leads to its classification as ssp. vaseyana; the acological setting is proper, the shrubs tend to be spreading and even-topped with broadly cuneate to spatulate persistent leaves and with terminal leaves giving the appearance of being whorled. However, such shrubs tend to be restricted to the more mesic environments of the area, with a shorter, uneven-topped variety occupying the relatively xeric sites. This short growth form has the general growth habit of ssp. wyomingensis but leaf shapes and ecological context are not quite right. Fortunately, soluble compounds in the leaves of big sagebrush have been found to be reliable indicators of subspecies taxonomy (Hanks, et al. 1973; Stevens and McArthur 1974; and Winward and Tisdale 1977). When crushed leaves are mixed in alcohol or water, then held up to a longwave ultraviolet light, ssp. vaseyana fluoresces creamish-blue. Over twenty big sagebrush samples were collected from mesic and xeric sites in the study area and subjected to the fluorescence test; all samples indicated that the only subspecies present is vaseyana.

The available literature suggests that of the three big sagebrush subspecies, ssp. <u>vaseyana</u> has relatively high palatability to deer and sheep (Sheehy and Winward 1981; Welch et al. 1981). A sample of black sagebrush was tested under ultraviolet light, and yielded a creamish-blue

response, which is indicative of a relatively palatable genetic strain of that species (Stevens and McArthur 1974). An excellent summary of the relative differences between the subspecies of big sagebrush among a variety of characteristics such as growth habits, phenology, etc. has been prepared by McArthur (1982). The genetic/ecological site combination for mountain big sagebrush generally result in high growth rates for sagebrush, high ground cover and density, but also high community floral diversity (Winward 1982).

Although the examination of big sagebrush did not yield the identification of separate subspecies, as expected, there is significant management significance associated with the tall and short growth forms of mountain big sagebrush mapped. It is quite probable that a genetic difference exists between the big sagebrush found on relatively xeric sites and on the mesic sites on Parker Mountain. Since it has been suggested that ssp. wyomingensis may have arisen as a result of hybridization between ssp. vaseyana and Artemisia nova (McArthur et al. 1979), what is called short form mountain big sagebrush in this study may be a similar sort of hybridization of local strains, leading to genetic form of ssp. vaseyana which bears habitat and growth form characteristics similar to ssp. wyomingensis. For purposes of this study, management recommendations for short form mountain big sagebrush sites will be taken from available literature regarding ssp. wyomingensis and Artemisia nova. The possibilities that this cover type might represent other forms of ssp. vaseyana (i.e., "spiciformis," and "xericensis") has been explored but the combination of characteristics does not fit the model for such species forms.

A final aspect of the legend for Appendix A is the notation of range improvements. Solid black polygons indicate the locations of ponds or reservoirs. Watering troughs are also noted. Some of the water developments are quite small, so map polygons have been exaggerated to make the locations of water more visible. Many of the water developments and cattle guards are visible from the photography or were noted in the field. Some recent developments were taken from Division of State Lands and Forestry records. The water developments represent a wide variety of storage capacities, and probably vary significantly with regard to water quality, loss rates, etc. Future efforts should be directed toward naming each water development and cataloging its attributes.

An inventory of vegetation types from the map overlay (Appendix A) is presented in Table 1. Pasture totals are shown and subtotals for major vegetation types are shown to permit comparisons with the Landsat inventory, below. From this inventory, the eight pasture study area has the following relative composition of cover types: aspen, 14.5%; tall growth form mountain big sagebrush (including pinyon-juniper), 30%; short growth form mountain big sagebrush, 15.5%; black sagebrush, 38%; and mountain silver sagebrush and wetland, 2%.

It should be noted that Table 1 presents plane acreages. Actual ground surface areas exceed map areas according to the steepness of the terrain. However, land slope must be quite steep before significant inaccuracy is encountered. The present surface acreage increase over map acreage for areas up to 25%, 35%, and 45% slope is 3%, 6%, and 10%, respectively (Anderson 1972). Since the percent acreage increase for 40% slopes is 8%, and slopes in the study area are generally less than 30%, the inventory in Table 1 is probably within 5% of actual surface acreage.

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Table 1. Acreage tabulations for photo interpreted map land cover classes within eight pasture units.

				PAST	URES			- 1	
Map Symbol*	Parker Hollow	Red Knoll	Parker Knoll	Parker Lake	Nicks	Buttes	South	Dry Wash	Area Total
a	1,775	175	1,227	337	1,033	280	621	17	5,465
a '	0	0	0	0	155	0	0	0	155
f	0	0	14	0	10	0	0	0	24
f/a	33	0	2	0	3	0	0	39	77
Aspen subtotal	1,808	175	1,243	337	1,201	280	621	56	5,721
p (pinyon-juniper)	0	0	0	0	0	0	0	101	101
t	1,725	1,731	1,939	2,533	1,726	1,326	511	166	11,657
t'	0	0	0	0	70	8	0	0	78
Big sage, tall form subtotal	1,725	1,731	1,939	2,533	1,796	1,334	511	166	11,735
S	671	1	805	394	1,528	1,055	1,336	108	5,898
s'	0	0	0	0	201	20	0	0	221
Big sage, short form subtotal	671	1	805	394	1,729	1,075	1,336	108	6,119
n	115	2,518	280	2,528	305	3,113	5,420	315	14,594
n/s	100	19	4	81	0	0	118	0	322
Black sage subtotal	215	2,537	284	2,609	305	3,113	5,538	315	14,916
c (silver sage)	47	2	128	190	118	134	0	0	619
w (wetland)	10	0	7	54	8	2	0	0	81
PASTURE TOTAL	4,476	4,446	4,406	6,117	5,157	5,938	8,006	746	39,292

<sup>\*</sup>See text for a description of map classes.

Surface acreage underestimation for steep slopes increases rapidly when slopes exceed 40%: 50% slopes, 12% acreage increase; 60% slopes, 17%; 70% slopes, 22%. It is not certain whether range inventories on steep slopes necessarily leads to an underestimation of grazeable forage since it has not been shown that steep slopes produce more vegetation per unit of horizontal area than do moderate slopes (Anderson 1972). It is probably wise to ignore the positive bias for acreage measured in areas with steep slopes when determining carrying capacity because the vegetation cover on steep slopes is particularly important for soil stability and water infiltration.

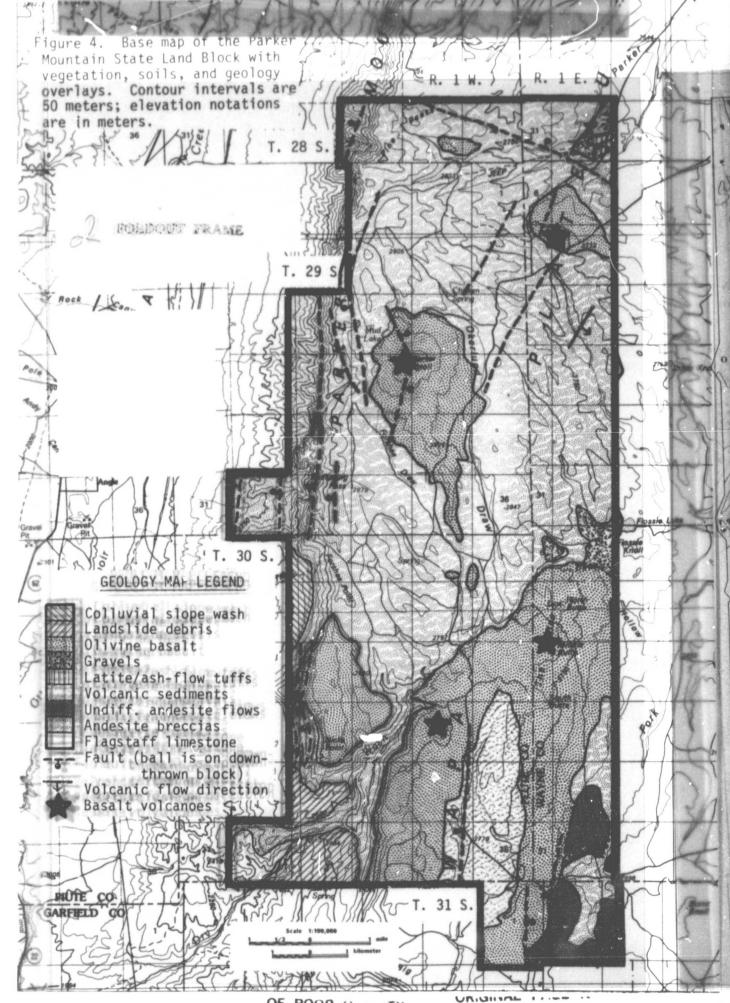
#### Integration of Photo Interpreted Map with Other Maps

This study has focused on synthesizing all relevant information pertaining to Parker Mountain resources to augment multiple resource management. The process of integrating ancillary information regarding geology, soils, and precipitation assisted in the interpretation of CIR photographs as well as Landsat print maps and spectral signatures. Such ancillary map information is also valuable to the resource manager in its own right; the maps presented below are intended to enhance overall understanding of environmental relationships which is fundamental to resource management.

Surface geology is often a very visible component of the Parker Mountain landscape, and is a vital link in understanding the ecology of the area. The geology map overlay in Figure 4 permits a fairly detailed overview of how surface geology relates to soils and vegetation patterns (from Williams and Hackman 1971). The vegetation overlay in Appendix A was generalized spatially and reduced to permit the comparison of vegetation patterns with geology and soils in Figure 4. The Awapa Plateau

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is characterized by various types of Tertiary and Quaternary volcanic deposits which have covered underlying sedimentary rocks. Only at the mouth of Dry Wash are sedimentary limestone deposits exposed in the study area. Details regarding the geologic materials mapped in Figure 4, including relative ages of geologic materials and estimates of when the materials were formed, are presented in Appendix B.

The geologic history for the study area has been worked out, and apparently mapped, quite well (Williams and Hackman 1971; Hintze 1979). Sedimentary tock (i.e., limestone) was initially covered with massive mudflow volcanic breccias. The breccias were then covered with latite flows and ash-flow tuffs. The tuffs were next covered by volcanic sediments. Apparently the sources of these volcanic deposits were not to be found on Parker Mountain itself, but from volcanic activity nearby; hence the rather complete layering of deposits. Faulting uplift of the western edge of the Awapa Plateau was occurring most likely throughout this period, which initiated differential erosion rates of the overlying volcanic deposits. For this reason, one finds the oldest volcanic material (breccias) exposed on the western edge of the plateau, but finds younger volcanic sediments and tuff flows moving eastward. This process led to the formation of the hill-swale character to the topography where breccias are the dominant surface geologic feature. Within the last few million years, after much erosion had already taken place, local volcanic activity occurred on Parker Mountain forming volcanic cones such as Parker Knoll, Red Knoll, and the Buttes and creating local basalt flows, some of which weathered rapidly to form gravel deposits in low areas. Most recently, unconsolidated deposits have been created as a result of faulting activity and canyon wall sloughing along the western edges of the study area.

This background geologic history provides the primary explanation as to why Parker Mountain appears as it does. Present-day soils and topography, and therefore plant distribution, are linked to the prehistoric processes outlined above. The differences between areas overlying basalt flows and breccias include differences in topography, soil parent material chemical properties and weatherability, and amount of time (and associated climatic regimes) available for soils to form. As noted in the description of the vegetation map legend above, surface geology appears to influence the distribution of some plant species and subspecies. Some species, such as black sagebrush, occur on a variety of geologic materials but the nature of the sites (i.e., soils, aspect, surface rockiness) is sufficiently different to justify managers taking note of the underlying geology.

Surface soils are of primary importance in managing rangelands. The soil characteristics of a given site are a reflection of soil parent material, topography, climate, plant and animal influences, over time. In connection with the 1961 Parker Mountain range conservation plan, a soils map was prepared by the S.C.S. That map has been adapted as an overlay in Figure 4. It is recommended that the user color in different soil units with different colors of permanent ink pens (e.g., SCUF Pilot pens) to facilitate the interpretation of Figure 4.

The soils in the study area fall into four main soil series: Faim, Forsey, Foy, and Parkay. An unnamed series found in Dry Wash is most likely a Parkay/Forsey complex. The taxonomy and major characteristics for primary soil horizons for a typical 60-inch pedon for each soil are presented in Table 2. The taxonomic class "Cryoboroll" reflects the soils on Parker Mountain formed under glassland steppe vegetation with

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Table 2. Summary of major soil horizons and characteristics. Detailed soils descriptions may be found in Appendix C.

Taxonomic Class	1				vallable Water
Tavolleulie olasi	Name	Depth	Thickness		apacity .n./in
fine, montmorillonitic	01	05 fn.	0.5 ln.	(twigs and duff)	
Argic Pachic	AT	0-14 fm.	14-17 in.	loam	0.14-0.17
Cryoborolls	82 t	14-33 in.	15-43 in.	heavy clay loam	0.17-0.19
	B3t	33-41 in.	0-15 in.	clay loam	0.17-0.19
	С	41-60 in.		very cobbly loam	0.09-0.12
loamy-skeletal,	Α1	0-8 in.	8-15 in.	cobbly loam	0.11-0.14
mixed Argic	B2t	8-23 in.	7-20 in	very cobbly clay loam	0.09-0.13
Pachic	B3t	23-30 in.	0-7 in.	extremely cobbly	0.09-0.13
Cryobarolls	c	30-60 in.		extremely cobbly loam	0.08-0.10
loamy-skeletal	Al	0-7 in	6-11 in.	cobbly loam	0.10-0.13
mixed Argic	B2t	7-17 in.	9-17 in.	very cobbly loam	0.07-0.12
Cryoborolls	CI	17-23 in.	6-20 in.	very cobbly sandy loam	0.06-0.10
	C 2	23-60 in.		very cobbly sandy loam	0.06-0.10
fine-loamy,	A11	0-5 in.	5-8 in.	heavy loam	Information
mixed Typic	A12	5-11 in.	5-8 in.	heavy loam	Not
Cryoborolls	B1	11-23 in.	11-13 in.	clay loam	Available
ļ	B2	23-40 in.	15-20 in.	clay loam	
	c	40-60 in.		clay loam	
-	Argic Pachic Cryoborolls  loamy-skeletal, mixed Argic Pachic Cryoborolls loamy-skeletal mixed Argic Cryoborolls  fine-loamy, mixed Typic	Argic Pachic Al Cryoborolls B2t B3t C loamy-skeletal, Al mixed Argic B2t Pachic B3t Cryoborolls C loamy-skeletal Al mixed Argic B2t Cryoborolls C1 C2 fine-loamy, All mixed Typic Al2 Cryoborolls B1 B2	Argic Pachic Cryoborolls  B2t 14-33 in. B3t 33-41 in. C 41-60 in.  loamy-skeletal, Mixed Argic Pachic B3t 23-30 in. Cryoborolls Cryoborolls Cryoborolls Cryoborolls Cryoborolls Cryoborolls Cryoborolls Cryoborolls Cli 17-23 in. C2 23-60 in.  All 0-5 in. Mixed Typic Cryoborolls B1 11-23 in. B2 23-40 in.	Argic Pachic Cryoborolls  B2t 14-33 in. 15-43 in. B3t 33-41 in. 0-15 in. C 41-60 in.  C 41-60 in.  B2t 8-23 in. 7-20 in B2t 8-23 in. 7-20 in B2t 8-23 in. 0-7 in. Cryoborolls  Cryoborolls  Cryoborolls  Cryoborolls  Cl 17-23 in. 6-20 in. C2 23-60 in.  All 0-5 in. 5-8 in. B1 11-23 in. 11-13 in. B2 23-40 in. 15-20 in.	Argic Pachic  Cryoborolis  B2t 14-33 in. 15-43 in. heavy clay loam  C 41-60 in.  C 23-30 in.  C 7-20 in  C 41-60 in.  C 41-60 in.  C 41-60 in.  C 41-60 in.  C 23-30 in.  C 7-20 in.  C 41-60 in.  C 23-30 in.  C 7-20 in.  C 30-60 in.  C 21-7 in.  C 30-60 in.  C 23-60 in.  C 30-60

unsaturated soil moisture conditions, with mean annual soil temperature of less than  $47^{\circ}F$  and mean summer soil temperature of less than  $57^{\circ}F$  (Buol, et al. 1973).

The Forsey, Faim, and Parkay soils all have an argillic horizon (i.e., B2t and B3t), which is a subsurface horizon characterized by the accummulation of illuvial clays. This horizon forms below the "A" horizon, a surface or near-surface mineral horizon which is relatively high in humified organic matter, dark, and with a base saturation greater than 50%. The argillic horizon is a transition zone to the "C" horizon: a mineral layer which is experiencing geologic weathering but is relatively unaffected by pedogenic (soil forming) processes (i.e., biologic activity, leaching, etc.) (S.C.S. 1975). Besides an absence of an argillic horizon, Foy soil has a relatively low base saturation (lower pH), which indicates it receives run in water.

Among the Faim, Forsey, and Parkay soil series, thickness of the mollic epipedon appears to be linked with site potential for producing forage. The Faim and Parkay soils include the intergrade "Pachic" in their taxonomic class. This means that the mollic epipedon (i.e., "A" and "B" horizons) is relatively thick (S.C.S. 1975): commonly greater than 16 inches thick for Faim and Parkay soils (S.C.S. 1982). This difference in mollic epipedon thickness appears to reflect basic differences in the climatic/topographic influences between Forsey soils and Faim and Parkay soils. The Forsey and Parkay soils are fundamentally different from Faim soils in that they contain greater than 35% rock fragments in their control section. The Faim soil also contains an accumulation of greater than 35% clay in its B2t horizon, which is greater than the other two soils. See Appendix C and Appendix D for greater detail regarding typical horizon characteristics and ranges in horizon features (source: S.C.S. 1982).

Narama**nd** Lilling agus a Lilliag a' gleat i learn à lear the Al-Mailte aireal **a L**illian aireann ann an Airb

Although fairly detailed soil profile descriptions are available, the soils map should be used with some caution. Vegetation patterns, as well as background geology and geomorphic processes, are the primary features used in mapping soils. The soils on Parker Mountain were mapped without the advantages of CIR photography, Landsat data, detailed surface geologic interpretations, and present accessibility of the study area to vehicular travel. Consequently, were the mapping to be performed again, greater interpretive accuracy would result. In addition, instead of mapping many areas as soil complexes, greater spatial accuracy and detail would certainly result. Use of the soils map in Figure 4, combined with other map information, will allow the user to predict the soil series at a given site with a fair degree of accuracy.

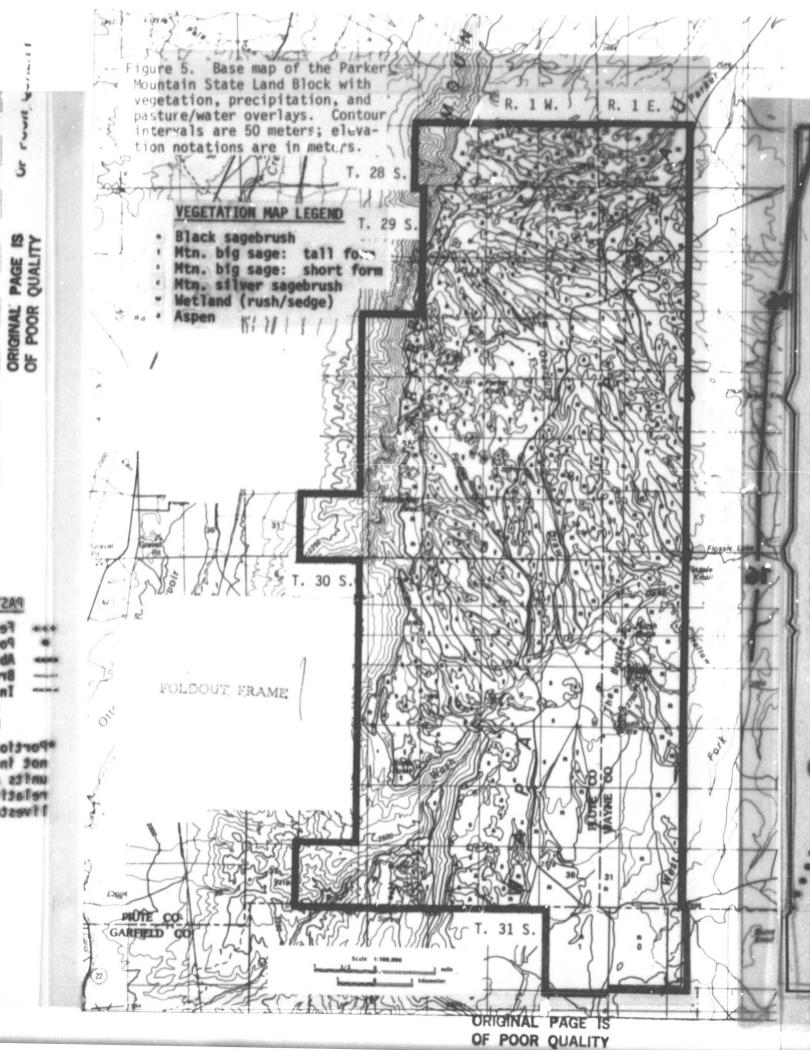
The plant communities which have been mapped within the study area appear to be very reliable indicators of available soil moisture. The upland plant communities are also good indicators of the type of argillic horizon to be expected on a given site. A closer look at the pedogenic processes which give rise to the formation of argillic horizons in rangeland soils will assist in understanding the moisture-gradient ecology of plant communities on Parker Mountain.

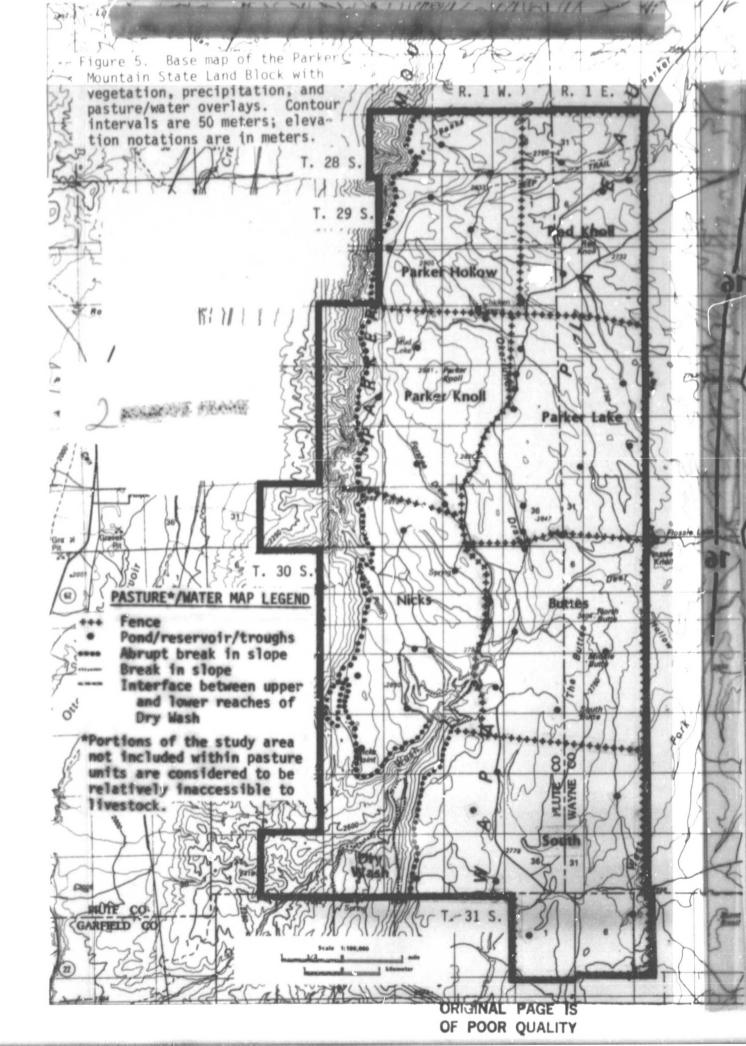
The presence of an argillic horizon in a soil indicates several things. First, there must be a source of illuvial silicate clay or free iron. Andesite and basalt are rich in iron and magnesium bearing minerals which are easily weathered to yield clay and free iron (Buol, et al. 1973). The clay in the soils on Parker Mountain appears to be mostly montmorillonitic, with a high shrink-swell capacity. Next, there must be a mechanism which leads to the translocation of clay particles to a point at which they may accumulate. The wetting of a dry soil favors dispersion of clay particles,

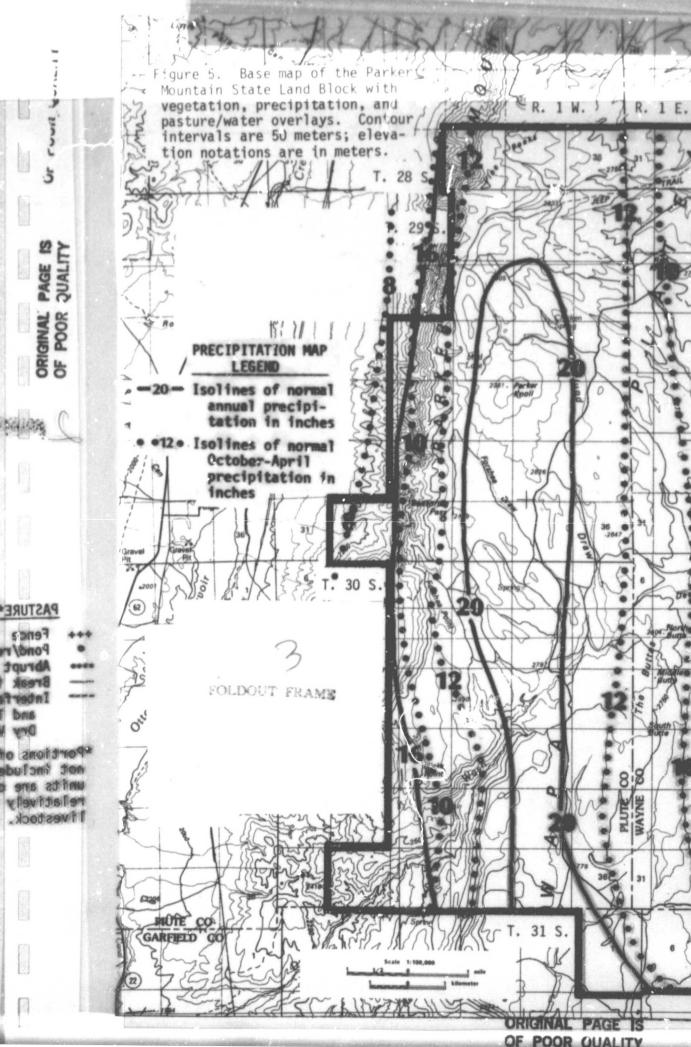
which then percolate through the soil profile. Clay accumulates lower in the profile where the soil becomes partially or thoroughly dried during the year. Water percolating in noncapillary voids is then stopped by capillary withdrawal by clay deposits on the walls of capillary voids. The presence of lime, magnesium, and sodium also assist in stopping the percolation of clay. Finally, a vital element in the formation of the argillic horizon is time. Since the processes described above are extremely slow, the presence of an argillic horizon indicates the lack of disturbance of the surface soil. The formative processes require a few thousand years, and the "mixing of horizons by animals, by frost, and by shrinking or swelling must be slow or absent." (S.C.S. 1975).

The foregoing discussion provides an explanation for the vegetation "islands" encountered in the study area on sites of abandoned prairie dog mounds. Such islands support the growth of species which are generally confined to more mesic sites. The islands also appear to produce greater plant biomass per unit area. This phenomenon demonstrates the influence of the argillic horizon on plant growth. The soil descriptions in Appendix C indicate that most plant roots are confined to the "Al" horizon. Thus, the relative suitability of the Faim, Parkay, and Forsey soils for providing a moisture reservoir for plant growth is quite obvious from Table 2. Therefore, intensive upland range improvements should be concentrated primarily in areas with Faim soils, with lesser efforts on Parkay soil sites, and probably no effort should be expended on Forsey soil areas.

The distribution of vegetation and development of soils appears to be largely a reflection of macro and micro climatic variations throughout the study area. Figure 5 contains a precipitation overlay which presents







isohyets for mean annual and dormant season precipitation (source: U.S. Weather Bureau 1966). A combination of prevailing winds and orographic influences lead to maximum total precipitation (ca. 21 inches) along the center of the western half of the study area, which decreases most significantly as one moves eastward.

Temperatures probably vary somewhat throughout the study area but average 39°F for mean annual temperature, and 54°F during the summer (S.C.S. 1982; B.L.M. 1979). The mean maximum and minimum temperatures for January are 34°F and 8°F, respectively. The respective mean maximum and minimum temperatures for July are 80°F and 48°F (Jeppson, et al. 1968). The frost-free season varies from 65-80 days (shorter at higher elevations), and occurs between mid-June and mid-September. Potential evaporation is approximately 18 inches in the eastern half of the study area, and 18-21 inches in the west (Jeppson, et al. 1968).

The majority of precipitation falls as snow and rain during the dormant season. This is the most reliable source of moisture for annual plant growth. Warm summer temperatures and soil moisture deficiencies lead to the maturity of most herbaceous plants between June and July. Cooler temperatures and summer rains in August and September allow some greening up of vegetation prior to winter dormancy.

Local topography influences micro climatic patterns which lead to differences in site capability for producing forage. Potential evapotranspiration is higher than average conditions for south to west facing aspects as a result of higher air and soil temperatures, and increased exposure to the dessicating winds common to the study area. Wind also has a great ability to affect local moisture patterns by the relocation of snow into drifts. Local topography and vegetation height

exert the greatest influence on snow accumulation where wind speeds are sufficient to transport snow. Drifts that develop in natural catchments often persist several weeks after the general snowpack has melted (Sturges 1979). On Parker Mountain, late spring snowdrifts are common among aspen forests and tall growth form big sagebrush in protected slopes and in swales. Such accumulations play an important role in the supplying of water to springs and reservoirs, and improvements such as snow fencing may be used to significantly augment snow accumulation. (Sturges and Tabler 1981).

Figure 5 also highlights the sources of surface water inventoried in this study. A total of 49 water sources have been identified. Each pasture contains from 5 to 10 water resources, except for Dry Wash, which does not appear to have any water developments. Generally, water developments are within one mile from any given point in the study area, and rarely over one and one-half miles. As noted above, there remains a need to carefully assess the adequacy of each existing water resource to meet management goals for subunits of the study area.

Range managers often attempt to incorporate the foregoing analysis of environmental factors into a single concept: the ecological range site. The ecological range site (hereinafter "range site") is a "distinctive kind of rangeland that differs from other kinds of rangeland in its ability to produce a characteristic natural plant community " (S.C.S. 1976). The natural plant community or climax community is that assembledge of plants that would eventually occupy a site in the absence of abnormal disturbances and physical site deterioration. Range sites are derived from the analysis of vegetation composition (by dry weight) from clean up sites. Plant association tables are prepared and analyzed for significant

differences in the kind of dominant species and species groups, proportionate make up of dominant species and species groups, and total annual production. Thus, definition of range site and designation of an area as being that range site, provides a single expression of all environmental factors responsible for the development of that range site. The range site concept has, therefore, become a key component in the use, development, and rehabilitation of rangelands. Although a given range site model may oversimplify the inherent variability in nature, it is nevertheless a valuable and adaptable tool for developing rangeland management plans.

Range sites are mapped from an analysis of physical indicators which are associated with the range site. In this study, ecological conditions encountered on Parker Mountain suggest that twelve major range sites are present in the study area. These ecological sites have not been mapped per se, but may be approximated by reference to Table 3, Appendix A, geology and soils maps of Figure 4, and the Landsat digital print map. Further examination of plants and vegetation in the field will be helpful in identifying range sites.

A primary advantage of the range site approach to range inventory and analysis is that it provides a model for assessing the current stage of plant community succession. Departures from the climax plant community model occur from a variety of causes including grazing, fire, mechanical disturbances, etc. The concept of range condition describes the present state of vegetation of a range site in relation to the potential natural community for the site (RISC 1980). Condition for grazing management is assessed by categorizing plant species according to their response to grazing and their presence, by weight, in the



Table 3. Ecological range sites in study area, and associated photo interpreted land cover, geology, soils, and Landsat map symbols.

		)	ssociated Map Chara	cteristics	
Ecological Range Sites	Relative Abundance**	Land Cover*	Geology (Figure 4)	Soils (Figure 4)	Landsat Map Symbol(s)
high mountain loam	35%	"a" aspen, and "f/a" conifer/aspen	breccias (rarely basalt)	Faim	Various "0"
high mtn. stony loam	50%	N N 0	breccias & basalt	Parkay	Various "0"
high mtn. shallow loam	151		basalt flow	Parkay	Various "0"
semi-wet meadows	A11	"c" mtn. silver sage	breccias	Foy	*. *
wet meadows	A11	"w" wetland	breccias	Foy	W
mountain loam	50%	"t" mtn. big sagebrush, tall growth form	breccias (rarely basalt)	Faim	√, U
mountain stony loam	50%		breccias (some basalt)	Parkay	1
mountain stony loam	70%	"s" mtn. big sagebrush, short growth form	breccias & basalt	Parkay (some Forsey)	R, S, +, -
mountain shallow loam	30%		basalt flow	Parkay (some Forsey)	٠, -
upland stony loam	65%	"n" black sagebrush	basalt, breccias and sediments	Forsey (some Parkay)	Blank, ', '
upland shallow loam	35%	36 44 14	basalt flow	Forsey	^, •
upland stony loam (juniper)	A11	"p" pinyon-juniper	landslide debris	Parkay (some Forsey)	Various

Photo interpreted map, Appendix A.
 Refers to estimated relative ecological range site abundance within the photo interpreted map cover classes.

potential natural community (Avery 1975). If a plant is not in the native vegetation, it is technically an "invader." Invader species are often undesirable plants, usually because of relative unpalatability, short time of availability, or toxic or other injurious properties. Plants which are in the native community but which decrease in abundance under heavy grazing are "decreasers" or "preferred" species. Other plants, which are part of the native community and tend to increase in abundance with heavy grazing, are "increasers." These plants may be considered "desirable" in terms of palatability, but may only be available for a short time, may not produce much forage, etc., or may be relatively unpalatable (S.C.S. 1976).

Range condition for a given range site is evaluated by first clipping vegetation samples and determining community species composition on the basis of percent in dry weight of the site total. This information is then compared to natural plant community composition tables which then leads to the designation of excellent (100-76% climax species), good (75-51%), fair (50-26%), and poor (25-0%) range condition. A more appropriate set of adjectives would be climax, late seral, mid-seral, and early seral. This avoids the value judgments implicit in the former set of descriptions, which may or may not reflect corresponding levels of carrying capacity.

The information necessary to initiate range condition analysis for the range sites in Table 3 may be found in Appendix E; this contains natural plant community composition tables, total annual production estimates, and forage quality information taken from S.C.S. range site descriptions. Additional range site species information may be found in Mason (1978).

The plant composition information in Appendix E should be used as a starting point for initiating range condition analyses in the future. The 1961 range conservation plan assessed range condition on Parker Mountain to be generally poor, and fair in some areas. Although repeating a "cookbook" range condition analysis would be of some use, future field efforts should seek to maximize efficiency by adopting the procedures outlined below. The information in Appendix E and from other sources should be used to outline "desired and feasible," as opposed to potential natural, range site species composition. This establishes a plant composition goal which focuses on management goals, such as maximizing carrying capacity, floral diversity, etc. This approach allows the manager to use desirable introduced plant species in management programs without experiencing adverse consequences in condition class ratings. The manager would also decide that it is not feasible to work toward major forage composition changes in some areas, and could define the top condition rating in terms of a feasible goal. The suggestions noted above merely serve to yield condition class ratings from poor to excellent which correspond to vegetation condition as defined by management goals and the realistic expectations of a given site to produce certain plants. Emphasis should be placed on developing good and feasible management models which are tailored to meet the Parker Mountain study area situation, rather than adhering to standardized approaches to management. The exercise of sound professional judgment has been the basis of management in the past, and should continue to remain so in the future as management tools and information for Parker Mountain continue to be acquired. (See Wilson and Tupper 1982.)

#### Inventory from Landsat Data Analysis

The methods applied in the analysis of Landsat data initially expanded the number of spectral signatures before reducing the number of classes mapped to 20. A total of 49 signatures were developed from statistically searching the study area for representative signatures. Partitioning the study area based upon elevation, geology, and soils, as described previously, led to the creation of more than 10 additional classes. Grouping signatures to correlate with land cover differences based upon field observations and photo interpretation led to the following class designations:

Class No.	Landsat Symbol	Description
1.	89	Aspen: closed canopy, good health (i.e., bright red on CIR photo).
2.	8	Aspen: open canopy, good health.
3.	Ф	Aspen: forest patches or edges, fair-good health.
4.	θ	Aspen/sage: forest patches, fair-good health, significant influence (i.e., approximately 1/3 of pixel area) by tall growth form big sagebrush areas within or nearby.
5.	0	Aspen: open canopy to patchy forest, poor- fair health (i.e., pale red on CIR photo), big sagebrush influence.
6.	9	Aspen/conifer: forest edges, often on steep north-facing slopes.
7.	V	Mountain big sagebrush, tall growth form: loamy soil, mostly in western half of study area, often in moist bottom areas, usually with good grass understory.
8.	U	Mountain big sagebrusn, tall growth form: loamy soil, mostly in western half of study area, usually on north-facing slopes, usually with fair to good grass understory.

Class No.	Landsat Symbol	Description
9.	Т	Mountain big sagebrush, tall growth form: rocky soils, on various aspects in basalt flow areas in western half of study area, mostly on north-facing slopes in eastern half, probably often with patches of short growth form big sagebrush.
10.	S	Mountain big sagebrush, short growth form: in western half of study area, often on south facing slopes.
11.	R	Mountain big sagebrush, short growth form: mostly in eastern half of study area, usually with significant black sagebrush influence.
12.	+	Mountain big sagebrush, short growth form: mostly in western half of study area, south and west slopes.
13.	-	Mountain big sagebrush, short growth form: same as "+" but with tendency to occur higher up on slopes.
14.	^	Black sagebrush: mostly on basalt flows near Red Knoll and in southeastern portion of study area.
15.	,	Black sagebrush: occupies same area as " ^ " but usually with short growth form big sage- brush influence.
16.	٠	Black sagebrush: mostly on breccia (i.e., non-basalt) areas in northeastern portion of study area, southwest facing slopes, some mixing with short growth form big sagebrush.
17.	Blank	Black sayebrush: breccia areas in northeastern portion of study area, southwest-facing slopes.
18.	#	Mountain silver sagebrush: moist drainage bottoms, loamy soil.
19.	#	Mountain silver sagebrush: loamy drainage bottoms.
20.	W	Wetland: wet loamy soil, mostly rush/sedge with forbs.

The final selection of 20 classes represents a compromise between the goals of map simplification and preservation of meaningful (or potentially meaningful) detail. Limited ground truth at the present time does not permit a greater expansion of the descriptions set out above. It is anticipated that Division of State Lands and Forestry personnel will utilize the copies of digital print maps provided to obtain additional feedback regarding the nature of the Landsat classes. On the other hand, should some Landsat symbols prove to be an overgeneralization of actual cover differences, digital maps may be provided which contain a greater number of classes.

A portion of the final Landsat print map is presented in Figure 6. The area includes Red Knoll (upper right) and Parker Lake (lower left) and is printed at the same scale as Appendix A. A simplified (six classes) print map of the entire study area at 1:100,000 scale is shown in Figure 7. This figure may be registered with Figures 4 and 5 for comparison.

An advantage to digital mapping of rangeland resources is the ease with which the acreage of each Landsat class may be determined. After pasture boundaries in the study area were digitized, acreage calculations were made and are presented in Table 4. Subtotals have been made for six major vegetation types to facilitate comparison with acreage estimates from the photo interpreted map in Table 1. The overall Landsat inventory total is less than 1% below the total in Table 1. Pasture totals in Table 4 are within 1.5% of each corresponding pasture total in Table 1. These differences are attributable to minor differences in registration and results of software processing. The pasture totals for Table 1 are the more correct of the two methods.

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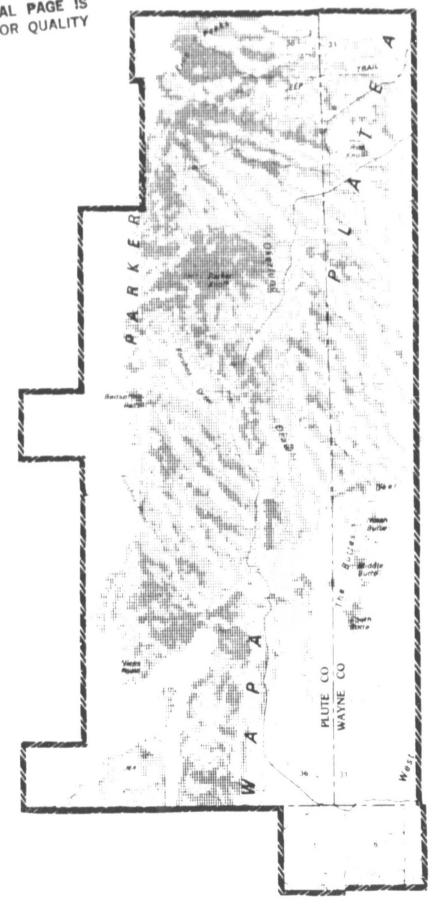
Figure 6. Representative portion of the Landsat digital print map. Twenty classes were mapped at scale 1:24,000.

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Figure 7. Base map of the Parker Mountain State Land Block combined with a simplified Landsat digital print map (i.e., with six classes). Scale is 1: 100,000.

#### Landsat Map Legend

Symbol	Description
*	Aspen
Χ	Mtn. big sage,
	tall form
-	Mtn. big sage,
	short form
blank	Black sage
A	Silver sage
W	Wetland



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Table 4. Acreage tabulations for 20 Landsat land cover classes within eight pasture units.

					PASTU	RES				
Class #	Landsat Map Symbol	Parker Hollow	Red Knoll	Parker Knoll	Parker Lake	Nicks	Buttes	South	Dry Wash	Area Total
1		369	17	54	32	154	29	73	0	728
2	B	685	42	288	123	445	50	176	2	1,811
3	•	544	55	424	128	492	76	171	5	1,895
4	9	119	55	533	172	244	110	174	18	1,425
5	0	14	0	149	9	39	19	22	0	252
6	0	40	0	18	0	30	0	42	59	189
Aspen Sut	ototal	1,771	169	1,466	464	1,404	284	658	84	6,300
7	٧	838	276	443	231	714	166	68	0	2,736
8	U	537	93	258	179	716	57	57	75	1,972
9	T	220	853	972	1,634	793	614	418	164	5,668
ig sage. Subtotal	, tall form	1,595	1,222	1,673	2,044	2,223	837	543	239	10,376
10	S	620	289	419	254	303	196	24	36	2,141
11	R	36	583	66	785	46	531	36	0	2,083
12	+	70	0	293	96	532	672	722	0	2,385
13	-	280	0	135	115	378	258	78	0	1,244
Big sage. subtotal	, short form	1,006	872	913	1,250	1,259	1,657	860	36	7,853
14	^	0	470	0	0	0	2,275	2,969	0	5,714
15	•	0	19	0	0	0	143	2,882	0	3,044
16	•	25	618	45	604	23	276	1	205	1,797
17	Blank	41	1,083	93	1,372	69	245	8	135	3,046
Black sag	ge subtotal	66	2,190	138	1,976	92	2,939	5,860	340	13,601
18	*	13	ŋ	66	120	89	93	3	0	384
19	1	0	0	112	147	72	95	0	0	426
Silver s	age subtotal	13	0	178	267	161	188	3	0	810
20	W (wetland	1	0	3	36	10	0	0	0	50
PASTURE	TOTAL	4,452	4,453	4,371	6,037	5,149	5,905	7,924	699	38,990

<sup>\*</sup>See text for a description of Landsat classes.

There is also general agreement among overall and pasture totals between Tables 1 and 4. The total for aspen in Table 4 is high because of the inclusion of big sagebrush cover associated with Class #4. differences among the big sagebrush and black sagebrush types are attributable to some fundamental differences in mapping procedures. Both mapping techniques have trade-offs in terms of spatial and interpretive accuracies which makes direct comparison of maps difficult: relative map accuracies must be judged by reference to available ground truth and in light of the particular spatial and interpretive accuracy specifications of each mapping project. Photo interpretation forces the mapper to generalize spatially to avoid creating map polygons which are too numerous and/or too small; interpretive generalizing and error occurs since vegetation boundaries are not always distinct and vegetation complexes occur but lines must be drawn to complete polygons. Landsat mapping includes numerous cells, which are equivalent to the photo interpreter's line-drawn polygons, thus offering the potential for increased spatial mapping detail. However, information obtained for each pixel by the Landsat scanner is already spatially generalized (ca. one acre resolution), which offsets this advantage somewhat. Landsat data is quantitative, and analysis of spectral values is more objective than photo interprotation. The Landsat spectral bands cover a narrower spectral range than most photographic emulsions and permit the analysis of single or multiple bands: aspects which often serve to simplify the process of associating light reflectance with ground cover. Error and generalizing in interpretation of classes occurs when the combinations of physical factors, which determine multispectral reflectance for different land cover types, produce similar spectral responses. Unless

such situations can be corrected by the use of ancillary data to digitize boundaries which avoid the confusion, misclassification of pixels will occur. Consequently, although Landsat analysis and CIR photo interpretation are both forms of remote sensing, comparing the products produced by both methods is similar to judging the difference between an apple and an orange. In addition, it can generally be assumed that ground truth is rarely available in such abundance as to permit good comparisons of the mapping approaches; Landsat maps are typically evaluated largely by reference to air photo interpretations, which leads to errors through misregistration or misinterpretation and bias that may inflate the apparent accuracy of maps from photo interpretation.

The photo interpretation map was used to illustrate the improvements to the Landgat map from the addition of ancillary information and to compare the spatial agreement between the two maps. The upper portion of Table 5 compares Landsat map class interpretations with corresponding classes on the photo interpreted map overlay. The two maps were compared by selecting a 3.5% regularly spaced samplin f Landsat cells, overlaying one map on the other, and recording the respective interpretations. Although inherent differences between the mapping approaches is not expected to produce perfect or even near-perfect agreement, an overall map agreement of 56% was judged unacceptable. Examination of the upper portion of Table 5 shows significant confusion between the tall and short growth forms of big sagebrush with both black sagebrush and silver sagebrush. Inclusion of ancillary data led to an overall map agreement of 77% (lower portion of Table 5). Examination of the instances of confusion between both maps does suggest that the source of disagreement lies in inherent differences in the two approaches, and not as a result of the inaccuracy of one map relative to the other.

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Table 5. Comparisons of range resources mapping from A. Landsat digital data and B. CIR photo interpretation.

Under table represents Landsat mapping from MSS data without use of ancillary data, lower table illustrates changes as a result of integration of ancillary data with MSS data.

				ANCILLARY	Annual Control of the					
			Α.	Landsat Map	Class Inte	rpretations				
₿.	Photo Interpreted Map Overlay	Aspen	Big sage, tall form	Big sage, short form	Black sagebrush	Silver :agebrush	Wetland	Total	Percent Agraement	Percent A/B Confusion
	Aspen	<u>157</u>	28	0	4	0	0	189	83	17
	Big sage, tall form	32	220	46	126	1	0	425	52	48
	Big sage, short form	3	62	<u>31</u>	143	0	0	239	13	87
1	Black sagebrush	3	19	20	319	1	0	362	88	12
	Silver sagebrush	0	19	46	5	<u>16</u>	0	86	19	81
	Wetland	2	20	0	ن	16	23	64	38	64
	Total	197	368	143	600	34	23	1,365		
	Percent Agreement	80	60	22	53	47	100	l		
	Percent B/A Confusion	20	40	78	47	53	0		Overal Agreem	

			AHCILLA	RY DATA INTE	Ì					
			Α.	Landsat Ma						
В.	Photo Interpreted Map Overlay	Aspen	Big sage, tall form	Big sage. short form	Black sagebrush	Silver sagebrush	Wetland	Total	ercent Agreement	Percent A/B Confusion
	Aspen	172	18	3	2	1	0	196	88	12
	Big sage, tall form	18	257	80	44	4	0	403	64	36
	Big sage, short form	1	57	<u>157</u>	4	6	0	225	70	30
	Black sagebrush	1	11	49	411	4	1	477	86	14
	Silver sagebrush	a	3	2	0	85	0	90	94	6
	Wetland	0	2	3	0	22	24	51	47	53
	Total	192	348	294	461	122	25	1,442		
	Percent Agreement	90	74	53	89	70	96	1		
	Percent B/A Confusion	10	26	47	11	30	4		Overal Agreem	

Conference of the second of th

Landsat map accuracy was assessed by randomly placing a grid, with ventions at ten-pixel row and column intends, over the Landsat map and photo interpreting the nearest group of 4-10 pixels of a given class. A total of 830 pixel groups (average group size was approximately 6) were examined, which represents a sample size of approximately 12% of all pixels. Table 6 presents an error matrix for six levels of vegetation cover interpretation. Overall map accuracy is 89%, with the greatest amount of confusion associated with short growth form big sagebrush. Map verification by examining pixel groups probably produces a positive bias over verification of individual pixels because it leads to the checking of areas on photos which are relatively homogeneous spectrally. However, simply looking at single pixels probably produces an opposite bias as a result of difficulty in achieving close registration between the Landsat map and photos. Sampling small groups of pixels is believed to be a good compromise, especially since pixels tend to occur as groups rather than as scattered individuals.

Judgiry from field observations and photographic consistency, overall accuracy of the photo interpreted map is estimated to be in excess of 90%. Thus, both maps have comparable accuracies despite less-than-perfect agreement. (See Table 5.) The user is encouraged to make primary use of the photo interpreted map since it is more accurate for most applications than the Landsat map, and is relatively easy to use as an overlay. The use of this map should be combined with the Landsat map for purposes of identifying more with evariations in range cover. Table 7 illustrates that the Landsat map, based on available field information and photo interpretation, contains fair to good accuracy for most of the 20 spectral classes. The overall accuracy is 74% with 21%

Table 6. Landsat map error matrix with verification for six levels of vegetation cover intrepretations.

Landsat Classes	Aspen	Big sage, tall form	Big sage, short form	Black sagebrush	Silver sagebrush	Wetland	Total	Percent Correct	Percent Commission
0,0,0,6,6,6	115	2					117	98	2
V,U,T		210	20				230	91	9
S,R,+,-		39	<u>106</u>	14			159	67	33
~,·,·,Blank		6	3	257			266	97	3
#,#		4	3		<u>48</u>		55	87	13
W						<u>3</u>	3	100	0
Total	115	261	132	271	48	3	830		
Percent Omission	0	20	20	5	ŋ	0	Overa Accura		

 $<sup>\</sup>star$ Verification of Landsat classes is based upon photo interpretation and field observation for regularly spaced pixel groups of 4-10 pixels each.

Table 7. Landsat map error matrix with verification for twenty levels of vegetation cover interpretations.

									-				٧	ERIF	IED	CLAS	SES*	,					1		
Class No.	Landsat Symbol	[]		2	3	4	5	6	,		3 9	10	11	12	13	14	15	16	17	18	19	20	Total	Percent Correct	Percent Commission
1		19		4	1																		24	79	21
2	8	6	3	4	6																		46	74	26
3	8			4 ]	4	1																	19	74	26
4	9			1	4	10					2												17	59	41
5	0						6															1	6	100	0
6	0							<u>5</u>															5	100	0
7	٧								42	17	3	3	********									$\Box$	65	65	35
8	U								13	<u>39</u>	, 1	2				}						١.	61	64	36
9	Ť								3	8	<u>78</u>	10	5										104	75	25
10	S								3	2	8	22	4										39	56	44
11	R								4	3	4	1	25	1	2		1	10	1				52	48	52
12	+										7			<u>30</u>									37	81	19
13	-										8		1		<u>20</u>			2					31	65	35
14	^										6		7			72	16				-		96	75	25
15	•															14	38	1					53	72	28
16	•												1					22	5				28	79	21
17	81ank																	2	87				89	98	2
18	+																			20	<u> </u>		20	100	0
19	#									4					3						20		35	80	20
20	W								_				_					-,		-		3	3	100	0
Total		25	43	2	5 1	1	6	5	65	73	123	38	38	31	25	86	55	37	93	20	28	3	830		
Percent Omissio		24	21	44	<b>!</b>	9	0	0	35	47	37	42	34	3	20	16	31	41	6	0	0	0	Overal	1 Accurac	y: 74%

\*Verification of Landsat classes is based upon photo interpretation and field observations. Class interpretations corresponding to the numbers for verified classes (columns) and Landsat classes (rows) follow:

#### Aspen

- 1. closed canopy, good health
- open canopy, good health
   patchy or edges, fair-good health
- patchy mix with big sage, fair-good health
   open canopy/patchy, poor-fair health
   mix with conifers, edges, north slopes

#### Mtn. big sagebrush: tall growth form

- moist loamy bottoms, grassy understory
   loamy north slopes, significant grass
   rocky, north slopes in east, various aspects in west

#### Mtn. big sagebrush: short growth form

- 10. western half of area, south slopes
- eastern half, mixes with black sagebrush
   western half, south slopes
   western half, south slopes

#### Black sagebrush

- 14. basalt flows
- 15. tasalt flows, mixes with big sage
- 16. breccia areas, southwest slopes, mixes with big sage17. breccia areas, southwest slopes

#### Mtn. silver sagebrush

- 18. very moist bottoms19. drainage bottoms

#### Wetland

20. wet soil, rush/sedge

average omission error and 23% average comission error. The Landsat map should be particularly helpful in ascertaining range sites (Table 3) and in selecting sites for future field sampling activities. In locating study transects, areas with dissimilar print characters should be avoided, or at least examined carefully before sampling vegetation.

One of the aspects of Landsat analysis is that there is a quantitative model (i.e., spectral signature) that accompanies each map print character. The spectral signature is often helpful in understanding the nature of the ground cover which produces the light reflectance measured by Landsat. Light signatures representing the 20 Landsat map classes are shown in Figure 8. Similarity in signature shape usually suggests similarity in ground cover type, whereas shifts along the vertical axis of a signature shape suggest changes in the amount of cover, moisture, aspect, etc.

Although not all signature shapes can be interpreted on the basis of apparent ground cover characteristics, and vice versa, some significant patterns in Figure 8 should be noted. In the upper figure, the flattening of the slope of the Band 6-Band 7 portion of the aspen signatures suggests an aspen cover/health gradient from symbol  $\blacksquare$  to 0. Significant sagebrush or barren understory influence is probably responsible for relatively high reflectance in Bands 4 and 5 for 0, 0, and  $\blacksquare$ . Symbol  $\P$  has low reflectance throughout, owing to presence of conifers and/or shadow.

The lower portion of Figure 8 illustrates some rather subtle variations in signatures. The solid lines (Symbols T, U, V) are all associated with tall growth form big sagebrush. Symbols U and T are lower in Bands 4 and 5 likely because of slope shadowing and in some cases, dark volcanic rock on the soil surface. Symbols U and V are

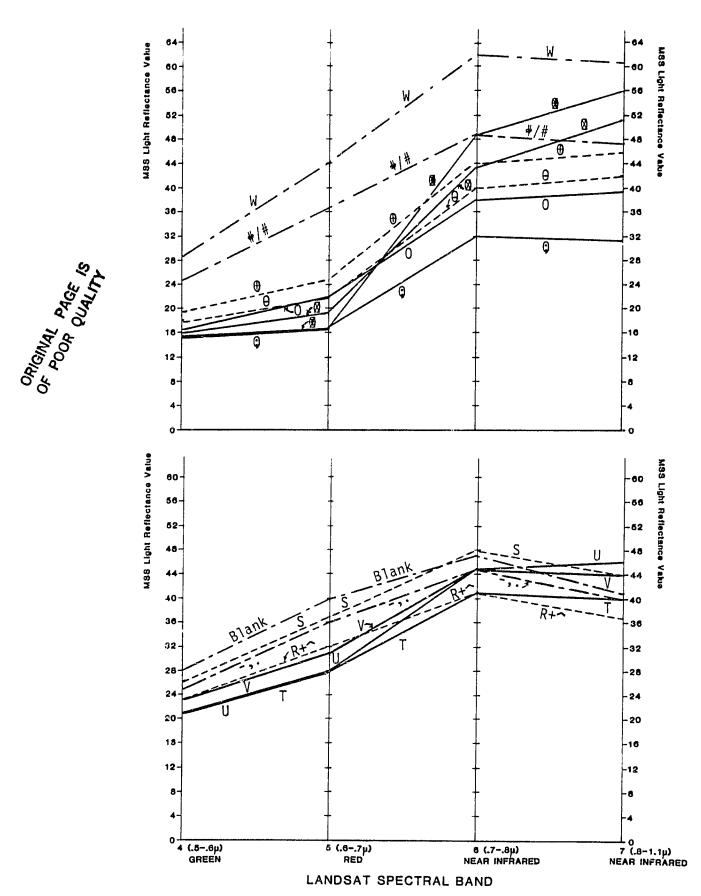


Figure 8. Light signature curves for wetland, silver sage, and aspen (upper figure), and sagebrush cover types (lower figure). Signatures are labeled with the corresponding Landsat map symbol or symbols.

relatively high, with a positive slope between Bands 6 and 7, suggesting relatively high biomass; the dropping of V relative to U in Band 7 may be a reflection of moist soils. The black sagebrush and short growth form big sagebrush signatures are higher in Bands 4 and 5, and have a negative slope between Bands 6 and 7. This suggests greater amounts of bare soil and surface rock. The curves with short dashes have a similar shape but the signature for Symbol S suggests greater overall reflectance, probably a result of southerly exposures. The same aspect relationship exists between the long and short dashed curves for black sagebrush. Further analysis of field conditions corresponding to the signatures will enhance the understanding of their shapes.

#### MANAGEMENT RECOMMENDATIONS

#### Field Work Planning

The primary purpose for remote sensing rangeland resources is to increase the efficiency with which sound management decisions may be made. This study has initiated the acquisition of a comprehensive data base for Parker Mountain natural resources, but additional information is vital. The field observations which have been made in this study were quite general, but sufficient for mapping purposes. Additional field sampling and observations are required to make the most of the maps that have been prepared.

Planning field efforts to obtain range management information is always a compromise between an idealized set of field resource information, and the realities of limited time, budget, and manpower. With this in mind, the recommendations prepared below are somewhat pragmatic because of assumed constraints on the Utah Division of State Lands and Forestry and the S.C.S. The techniques outlined are designed to permit a single field crew (i.e., one crew chief and three range technicians) to acquire a minimum of information within a period of one month.

Any plan for field work should also be a compromise between maximizing the number of study sites and maximizing the amount of detailed information to be acquired at each study site. The recommendations outlined below address the need for information regarding range condition, trend, and utilization, as well as carrying capacity. Information necessary to permit a meaningful assessment of these items should be acquired during the initial field season with a single half-day visit to each study site; this will yield information from approximately 41

study sites. Utilization assessments will also require a post-grazing season follow-up by a two-person crew for each pasture; this will probably involve two additional man weeks. After the first field season, annual sampling should be limited to utilization checks, with reassessments of condition, trend, and carrying capacity every three to five years. Additional background regarding the recommended procedures, and alternatives thereto, may be obtained by consulting range analysis handbooks for the Forest Service, S.C.S., and B.L.M., as well as relevant sections in Stoddart, et al. 1975. Avery 1975, and Blaisdell, et al. 1982.

Acquiring a set of CIR photography is an essential step in completing this initial inventory and analysis of rangeland resources. Access to the photography, which provides the basic data source for the overlay map (Appendix A), will help to minimize the amount of time to be spent in the field. Used in conjunction with the vegetation map, orthophoto quadrangles, and topographic quadrangles, the photography will also allow maximum benefit of field information via extrapolation to other sites which are photographically similar. As mentioned previously (see pages 29 and 30), the CIR photographs should be a primary tool in selecting field study sites; one can become reasonably certain of study site homogeneity as well as representativeness by looking at the photographs (in addition to other information already mapped). Finally, the photography will be a valuable asset for making comparisons with future CIR photography acquisitions in the area. Appendix F provides the information necessary for ordering the CIR photography used in this study. It is recommended that Option 4 in Appendix F be selected (total price \$195), should the purchase of full stereo coverage be infeasible.

Prior to carrying out field efforts, it would be well to develop standards for judging range conditions which are tailored to meet the ecological potential and management goals for Parker Mountain. A discussion was previously presented (page 51) which recommends guidelines for developing community composition lists for each ecological range site identified in Table 3. These guidelines are a hybrid between S.C.S. and Forest Service methods of assessing range condition. Range condition should be defined according to relative species composition, by air dry weight, as compared to "desired-feasible" species composition lists. The potential natural community composition list for each range site in Appendix E should be regarded as a first approximation of what is feasible for the range site. The lists should be modified to include desirable species, both native and introduced, known to occur on Parker Mountain or which are likely to successfully become established if seeded. Range managers should feel free to structure the species composition tables however necessary so that "excellent" in terms of range condition also means "excellent" in terms of management goals. In addition, range condition is best left as an expression of species composition of the plant community; factors such as total production, and soil condition are also important, but should not be included in preparing a condition rating. (See RISC 1980). The species composition tables should be finalized after additional field data and observations are acquired in the initial sampling efforts. (See Wilson and Tupper 1982.)

The initial field season should focus on establishing at least 41 permanent study sites: approximately one site per 1,000 acres of pasture. If administrative constraints do not permit more sites this season, additional sampling next season should increase the total number to 80.

The study sites should be divided up to provide samples from each pasture which are representative of major ecological range sites. The number of study sites for a given range site should be selected with reference to the acreage of that plant community in the entire study area and individual pastures, and the relative ability, both existing and potential, of the plant community to provide forage and habitat. These criteria have been applied to produce a guide (Table 8) for selecting the initial group of 41 study sites. Of the 41 total sites, 8 have been assigned to aspen areas, 2 to mountain silver sagebrush, 1 to wetland, 13 to tall growth form mountain big sagebrush, 6 to short growth form mountain big sagebrush, and 11 to black sagebrush.

Once the study sites have generally been stratified among the pastures and range sites, the approximate location of each site may be made using available maps. Each site should be selected on the basis of environmental homogeneity, representativeness, and accessibility. Environmental homogeneity (i.e., vegetation, % slope, slope position, aspect, soils) may be assessed quite accurately in the office from the CIR photography, photo interpreted map (Appendix A), the Landsat map. soils and geology maps, and topographic quads. Representativeness of the site's environmental factors may also be assessed from the abovenoted materials. In addition, the amount of grazing use received by the site should also be representative of that plant community within the pasture, and should not be located in remote areas or next to water sources. The accessibility of a given site candidate may be determined by referring to the CIR photography and topographic quads. Despite the assistance provided by these various planning tools, site selection should ultimately be based upon experience and professional judgment of those persons interested in the management of Parker Mountain resources.

Guide for selecting initial group of 41 field study sites. Numbers in the table indicate the number of study sites for a given range site/map unit combination in a given pasture. Table 8.

					<del></del>				
	Dry Wash					~		<b>,</b> -	2
	South					-	-	2 2	9
	Buttes					~		2	4
.kES	Nicks			(1)			-		6 or 7
PASICKES	Parker Lake			or	<u>-</u>	2			1
	Parker Knoll			(3)					5 or 6
	Red Knoll						-		4
	Parker Hollow						<b>,</b>		9
	Landsat Class #/Symbol ***		2 C C 4	3 @ or 4 0	18 # 19 # 20 W	7 V 8 U 9 T	10 S 11 R 13 -	14 ° 15 ° 16 ° 17 Nank	
	Ecological Range Site **	high mtn. loam	high mtn. stony loam	high mtn. shallow loam	semi-wet meadows wet meadows	mountain loam mountain	stony loam & (mtn.	upland stony loam (& shallow loam)	Total
	Photo Interpreted Map Symbol *	ח ניס ניס	א ניהיניה ני	טייניה נ	UUZ		, w w w		=

\* See description in text pages 30-31, and acreage tabulations in Table 1, page 36. \*\* See Table 3, page 49, for a key to ecological range sites. \*\*\* See Landsat symbol descriptions in text pages 52-53, and acreage tabulations in Table 4, page 57.

Some of the permanent field study sites should be set up for the monitoring of forage utilization, or the percent, by weight, of total annual forage production consumed by livestock. Utilization should be assessed as soon as possible after animals are removed from each pasture. Within each pasture, utilization should be monitored on study sites which have been placed in key grazing areas. Each key grazing area should be a cross section of that range site within the pasture, or portion of the pasture, in terms of forage production, and accessibility Key forage species (i.e., highly palatable, abundant or potentially abundant, and widely distributed throughout the pasture). should be selected as indicators of grazing management for key areas. Key species are the most important, or potentially most important, forage species for each range site, and are the primary focus for managing seasonal livestock grazing. Identifying key species on key areas provides a practical means of planning and regulating grazing use to meet the management goals of an area.

A variety of methods are available for assessing utilization on rangeland. Comparing the utilization of key species in a key area with vegetation protected by wire cages is a straightforward method of determining utilization. This permits one to directly obtain weight estimates of utilization at the end of the grazing season.

The determination of range condition and carrying capacity involves the clipping of annual forage growth by species and converting field weights to air dry weight. Vegetation should be sampled when the major forage species reach the peak of production; this should occur between mid-June to mid-July, with the peak being reached in the eastern half of the study area first. Round, 9.6 sq. ft. plots are generally used

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for sage/grass ranges, but smaller plots (e.g., 2.4 sq. ft. or 1.92 sq. ft.) should be used where plant material is abundant and fairly uniform, such as in wetland areas. Plots should be located along a permanently marked transect or nested within a macroplot. A weight-estimate method should be applied with at least ten weight-estimate plots per study site of which a minimum of two plots should be clipped.

Adequacy () sampling should be assessed by the following formula:

$$n_{min} = \frac{t CV}{AE}$$

where,

nmin = minimum number of samples needed to meet
 established statistical criteria

t = value from "t" table for a given
 probability level

CV = coefficient of variation, or standard deviation divided by the mean, expressed as a percent

AE = percent allowable error

Sampling should continue at a site until "r<sub>min</sub>" is obtained for total production and major forage species. Good statistical criteria would be obtaining a "n<sub>min</sub>" which yields a 90% probability of being within 10% of a given mean. However, achieving an 80% probability of being within 20% of the mean is more realistic for most rangeland species. Generally, it is best to obtain weight estimates to a predetermined maximum such as 25 plots, of which 5-8 will be clipped. Applying these criteria assures greater consistency in the accurate characterization of vegetation composition on each site, while avoiding unnecessary collection of data.

In contrast to range condition, which is based on observations made at a single point in time, the assessment of range trend is made

from observations over time. Range trend is an assessment of the direction in which the plant community is going primarily in response to management practices. Since the production of plants is dependent upon variable amounts of annual precipitation, plant density per unit area is often used as a stable indicator of trend. Each study site should include a permanently marked 1/100 acre macroplot for which shrub densities are recorded. Within the macroplot, 3-5, 9.6 sq. ft. permanent plots should be located for which densities of major (also particularly desirable) grasses and forbs are recorded. This method provides data which have real management significance with a minimum of effort. The major problem in applying the method is defining what is to be regarded as "a plant." Generally, only established plants are counted, and definitions need to be developed for plants which have multiple stems or other confusing growth habits to assure consistency among field technicians. It is also advisable to take photographs of the trend plots, as well as the study site, for future comparisons.

The permanent plots established for assessing trend should also be used to estimate apparent trend, or indicators which suggest trend direction from a single observation. Both plant factors and soil factors contribute toward this assessment. Plant factors include characteristics which indicate the vigor and reproduction of desirable and undesirable plants. Soil factors include evidences of soil movement such as active gullies, plant pedestalling, amount of plant litter, wind scouring, etc. The Forest Service and S.C.S. have developed guidelines for rating apparent trends which should be consulted in developing a sampling technique.

It would be helpful if efforts were made to record some basic precipitation characteristics on Parker Mountain. Several inexpensive precipitation gages could be placed in the study area to aid in predicting seasonal forage conditions. This information would also add to the overall understanding of climate-vegetation influences on Parker Mountain.

#### Vegetation Resource Modifications

Management of range resources on Parker Mountain over the past 20 years has raised the present livestock carrying capacity to within approximately one-fifth of its potential. Current estimates of carrying capacity for land block pastures have been made by S.C.S. personnel based upon observations of forage utilization, as compared with the number and kinds of livestock and length of time spent in each pasture. These estimates of available A.U.M.'s in each pasture follow: Total 6,400; Parker Hollow 1,350; Red Knoll 600; Parker Knoll 850; Parker Lake 800; Nicks 900; Buttes 700; South 900; Dry Wash 300. Potential carrying capacity has been estimated from the herbage production information for ecological range sites in Appendix E. A 40% forage utilization factor was applied to the estimated average annual herbage production for range sites assumed to be "good" condition. The following figures for potential carrying capacity (acres/A.U.M.) resulted: high mountain loam 0.9; high mountain stony and shallow loam 1.3; semi-wet meadow 0.8; wet meadow 0.4; mountain loam 1.3; mountain stony loam 1.4; mountain shallow loam and upland stony loam (pinyon-juniper) 2.0; upland stony loam 1.6; upland shallow loam 2.2. Of course, potential carrying capacity should be estimated for Parker Mountain based on field sampling and range condition guides which have

been developed for local use, but these figures provide a good first approximation. Using the above information for present and potential carrying capacity, as well as the inventory information in Tables 1 and 4, the following comparisons of pasture carrying capacities have been made:

Pasture	Present acres/A.U.M.	Potential acres/A.U.M.
Parker Hollow	3.1	1.0
Parker Kncll	5.2	1.1
Nicks	5.7	1.2
Red Knoll	7.4	1.4
Parker Lake	7.6	1.4
Buttes	8.5	1.5
South	8.9	1.6
Dry Wash	4-6	1.4

The present carrying capacity estimate above for Dry Wash is only approximate since it is not clear from S.C.S. records how much of that pasture is considered grazeable.

The demand for A.U.M.'s is presently 5,121 for cattle (i.e., 1,138 animal units for 4.5 months) and 889 for sheep (i.e., 1,270 sheep, which are equivalent to 254 animal units, for 3.5 months). The present A.U.M. demand closely matches available A.U.M.'s since Dry Wash is not currently included in the annual grazing plans. In addition, grazing by big game in the study area probably results in the consumption of 200 to 300 A.U.M.'s annually.

Efforts to increase carrying capacity should be concentrated where the greatest impact to management goals may be achieved with minimum cost. The purpose of this section is to mention some guidelines for

deciding which areas to treat first, and for choosing the best methods for treatment. The recommendations herein assume that the primary management goal is to increase the amount, availability, and nutritional quality of forage for livestock. Additional goals include providing adequate wildlife habitat, and preserving the soil resource.

It will be necessary to intensify efforts to improve rangeland resources if significant progress toward achieving these goals is to be made in the near future. This includes brush control, seeding, fence construction, and other range improvements. The choice of a given management strategy should be based upon a cost/benefit analysis, which should include the following conditions: cost of the method; original forage production; expected increase in forage production; effective life of the project; requirements for deferment from grazing after treatment; and the effect of deferment on livestock operations (Nielsen 1979). These criteria have been applied, in a general sense, in preparing the management recommendations below.

There are several reasons why seeding introduced grasses under aspen forests should be a high priority on Parker Mountain. The aspen understory environment is well suited for providing some of the highest forage yields in the area. Prior to the 1961 grazing management plan, grazing pressure led to the destruction of the herbaceous understory in many aspen areas. Since that time, continued grazing under aspen, combined with lack of seed sources for adapted species has resulted in little improvement. Despite this open understory niche, shrubby species are not usually very abundant under aspen. Thus, there is no need for brush control prior to seeding, and there is little likelihood that a well established and managed grass-dominated understory will need to be

treated for brush control in the future. Good success has been achieved when adapted species are broadcast seeded just prior to aspen leaf drop (Laycock 1982; Vallentine, et al. 1963). Introduced grass seed adapted for growth in an aspen understory is readily available at a bulk seed cost of approximately \$0.75 per pound. Considering the cost of seed and labor, and the chances for success, increasing aspen understory production offers the greatest potential for both short-term and long-term increases in forage production.

It is recommended that at least 3,000 acres of aspen be seeded. The following is a suggested distribution of seeding efforts among pastures: Parker Hollow, 800 acres; Parker Knoll and Nicks, 750 acres each; South, 400 acres; and Red Knoll, Parker Lake, and Buttes, 100 acres each. The islands of aspen forest in the eastern pastures are a small portion of total land cover but improving understory productivity should add significantly to the pasture carrying capacity, since the possibilities for improving the black sagebrush areas are very limited.

The following seeding mixture is recommended for aspen understories:

Orchardgrass (Dactylis glomerata) 4 lb./ac.

Smooth brome (Bromus inermis, mixture of both northern 3 lb./ac. and southern strains)

Timothy (Phleum pratense) 1 lb./ac.

Intermediate wheatgrass (Agropyron intermedium) 1 lb./ac.

Legumes (e.g., alfalfa, Ladak variety) 1 lb./ac.

(See Plummer, et al. 1968; Laycock 1982; Vallentine 1980.)

Other adapted grass species, such as mountain brome (<u>Bromus carinatus</u>) and tall oatgrass (<u>Arrhenatherum elatius</u>), as well as forbs could be selected, but seed costs typically exceed \$4.00/lb. In addition, these introduced species typically offer the following advantages over native

plants: earlier green-up; extended season; seed is commercially available in quantity and is usually higher quality; better germination; longevity; and higher resistance to grazing pressure (Keller 1979).

Broadcasting seed in the fall just prior to leaf drop permits the creation of favorable moisture conditions after the leaves cover the seeds. New seedings under aspen should not be grazed the first year and should be deferred the second year until after seed has been set (Laycock 1982).

The ecological importance of sagebrush to a given area must first be evaluated before any management decisions are made. Various authors have made reference to historical accounts of early Western trappers and settlers to aid in understanding the pristine role and dynamics of sagebrush (Laycock 1979; Young, et al. 1979; Blaisdell, et al. 1982; West 1979; Beetle 1979). Some early writers emphasized the abundance of grass, while others made reference to the dominance of sagebrush, often forming dense stands with sparse understories. These historical records are simply too incomplete to provide a good assessment of pristine sagebrush ecology, and early writings can be used to justify nearly any preconceived ideas. However, there is general agreement in the literature that sagebrush has long been a basic part, if not a dominant component, of many western range ecosystems. Sagebrush was generally noted as increasing in abundance as one moved south and west in the Intermountain area, until true desert vegetation was encountered. There is no evidence from historical records that extensive changes in the distribution of sagebrush has occurred since the settlement of the West. If western ranges were true grasslands, then the increases in sagebrush that accompanied overgrazing would be reversed with relaxed grazing: something which rarely,

if ever, happens without the destruction of the sagebrush (Laycock 1979; West 1979). Therefore, the assumed herbaceous-dominated climax community conditions for upland and mountain ecological range sites in Appendix E may be understating the role of sagebrush in climax communities.

There is general agreement among sagebrush ecologists that fire is a natural component of many sagebrush-grass ecosystems. Fire is considered the main ecological factor that controlled sagebrush before settlement, particularly on mesic sites which allow the growth of an herbaceous understory with a dense sage overstory (West 1979; Blaisdell, et al. 1982). Such sites probably burned many times during their developmental history at estimated frequencies of 15 to 50 years (West 1979; Young, et al. 1979; Wright, et al. 1979). This periodic control by fire probably caused many of the valleys of central and western Utah to appear grass-dominated with fire-resistant bunchgrasses such as bluebunch wheatgrass and Great Basin wildrye (Young, et al. 1979).

A brief review of the characteristics of sagebrush which make it such an effective competitor for moisture may be helpful in the process of developing management prescriptions for the various sagebrush areas on Parker Mountain. Subtle differences in soil moisture, depth, temperature, etc., are important in determining the species, subspecies, and size of sagebrush on a site (Blaisdell, et al. 1982). Portions of the study area dominated by the tall growth form of mountain big sagebrush are probably characterized by well drained, deep soils with moisture available through most of the summer. These areas have the potential for producing the greatest amount and diversity of herbaceous forage or sagebrush among the sage-dominated sites, depending on how these areas are managed (Vinward 1980). Sagebrush has a growth period which is

quite similar to that of associated herbaceous vegetation. The root system for sagebrush is mostly diffuse, with extensive lateral spreading of roots, many of which are near the soil surface and allow shrubs to take advantage of summer rain (Sturges 1977a; Caldwell 1979). Deeper tap roots allow sagebrush plants to derive moisture from below the principal rooting zone of herbaceous species (Sturges 1977b). As the growing season progresses, sagebrush soil moisture use zones shift outward and downward to maintain growth (Sturges 1979). In addition to adaptations which lead to efficient extraction and conservation of water, there is also evicence that either water soluble or volatile compounds in sagebrush leaf litter inhibit the germination and growth of some associated species (Laycock 1979; Caldwell 1979; Hoffman and Hazlett 1977). Shrubs tend to be especially successful on xeric sites where they are adapted to encuring drought by drawing on deep soil moisture storage, and where a lower fuel volume lessens the chances for occasional fire (West 1979).

A review of recent literature regarding sagebrush management leads to the following conclusion: although the present abundance of sagebrush on Parker Mountain is in part a reflection of past overgrazing, significant improvements in grazing capacity will not occur by simply practicing good grazing management. Management plans should focus on the eradication of sagebrush on the most productive sites and, if needed, seed with adapted herbaceous species to improve forage production. Good grazing management will assure the success of range improvement efforts and prolong the effective length of treatment, but periodic control of sagebrush approbably every 10 to 20 years) should be expected to maintain highest productivity (Winward 1980; Beetle 1979; Winward and Tisdale 1977; Winward 1982).

An additional conclusion is that management of sagebrush ecosystems should focus on achieving the maximum sustained yield of forage and animal production consistent with maintaining the soil resource. Range management based upon theoretical natural plant community compositions will be frustrated by the difficulty, if not impossibility, and marginal utility of accurately describing a site's climax community (Laycock 1979; West 1979). Instead, the plants growing on a site should be regarded as a "phytometer" of that site's effective environment for accomplishing management goals (Young, et al. 1979). Range condition ratings should be designed to reflect the site's status, in terms of vegetation composition relative to management goals, and should be combined with like assessments of site production and soil condition (Miller and Tupper 1982).

Sagebrush should be controlled where it is tallest and thickest, where other undesirable plants are absent or will be controlled, and where seeding can be done promptly, if needed (Pechanec, et al. 1965; Keller 1979; Blaisdell, et al. 1982). It is recommended that the mountain big sagebrush on 3,000 acres in the eastern pastures be destroyed, as well as 2,000 acres in the western pastures. In the eastern pastures, big sagebrush should be controlled on the leeward side of small knolls. Such areas generally have the "T" symbol on the Landsat map. It may be necessary to avoid some sage grouse strutting grounds near Flossie Lake, otherwise there are no known conflicts with wildlife habitat needs. Sagebrush control in the western pastures should focus on areas near "#" symbols on the photo-interpreted map, and "U" and "V" symbols on the Landsat map, where brush cover is thickest. Particular emphasis should be placed on improving carrying capacity in Nicks pasture.

The selection of method to control sagebrush depends upon the nature of each site and an assessment of relative costs and benefits. The control treatment should kill the sagebrush, cause a minimum of damage to desirable species (if the area is not to be seeded), leave a good seedbed (if the area is to be seeded), and cause a minimum of soil loss. (See Blaisdell, et al. 1982.) Sagebrush is relatively easy to kill by using burning, chemical spraying, or mechanical methods. Spraying and burning generally require retreatment after 12 to 15 years, and mechanical methods can be expected to need retreatment after 20 to 25 years (Nielsen 1979). Generally, burning is considered the most economical treatment, where fire will carry, with chemical spraying preferred second, and mechanical methods (e.g., chaining, railing, discing, or plowing) yielding the lowest rate of return (Nielsen 1979; Pechanec, et al. 1965; Vallentine, et al. 1963). See Pechanec, et al. (1965) for an excellent review of sagebrush control methods, and Workman (1982) and Nielsen (1979) for guidelines on assessing the economics of sagebrush control.

Burning sagebrush is recommended as the most efficient method of control on Parker Mountain. Good burns under safe conditions may be obtained where sagebrush is sufficiently dense (at least one-third of the total cover) with an adequate herbaceous understory to carry a fire. Burning not only kills the sagebrush but, unlike spraying, also destroys the woody "skeleton" which may make some forage unavailable, and releases nutrients for growth. Where dense sagebrush stands are surrounded by black sagebrush, firelines are usually unnecessary, even with winds up to 25 miles per hour (Blaisdell, et al. 1982). Past prescribed burn plans on Parker Mountain have called for firebreaks around the entire burn unit. an expensive and often unnecessary precaution since black sagebrush

rarely carries fir? (Britton and Ralphs 1979; Wright, et al. 1979; Blaisdell, et al. 1982). Likewise, it should not be necessary to protect aspen from fire since abundant understory fuels are required to kill the overstory (Bartos and Mueggler 1981).

Since excellent guidelines for sagebrush burning are available (see Wright, et al. 1979; Blaisdell, et al. 1982), only some major points will be reviewed here. Sagebrush understories should have at least 20% cover of fire resistant perennial grasses or forbs or else revegetation plans should be made. Plants which are only slightly damaged by fire include coarse bunchgrasses and fine bunchgrasses with loosely clustered culms such as squirreltail, junegrass, Sandberg bluegrass, and the following wheatgrasses: western, bluebunch, intermediate, crested, and pubescent (Britton and Ralphs 1979; Blaisdell, et al. 1982). The bunchgrasses with densely clustered culms, such as needle-and-thread grass, and shrubs such as bitterbrush, are severely damaged by fire. Sprouting shrubs such as green rabbitbrush and horsebrush, both of which are present in the study area, rhizomatous grasses and forbs, and annuals are often benefited by fire; care should be taken to avoid burning areas with undesirable species known to benefit from fire, unless plans are made to control these species as well (Laycock 1979). Relative to other subspecies of big sagebrush, fire tends to have a positive effect on the seed germination of mountain big sagebrush (Winward 1982; McArthur 1982). Since sagebrush seeds in the study area probably mature between September and October, it would be best to plan burns in August or early September.

Since the rate of fire spread is a function of vegetation height, crown cover, herbaceous fuel loading, and moisture content, fires set in the fall spread at a rate two to three times that of fires in uncured

vegetation of early summer (Brown 1982). Spring burns may be successful after snow has melted, but before herbaceous growth begins, where there is a dry understory; burning at this time of year allows the high soil moisture level to protect plants and permit immediate growth. Summer burns are undesirable because soil moisture is low and herbaceous seed crops are destroyed. Early fall burns, before the onset of col moist weather, are more easily accomplished and produce good results.

Spraying sagebrush with 2,4-D, in the spring or early summer when shrubs are actively growing, is an effective means of brush control. (See Pechanec, et al. 1965; Blaisdell, et al. 1982; and Vallentine 1980 for guidelines.) This chemical is relatively non-persistent in the environment, but may harm non-target forbs or shrubs (e.g., bitterbrush) (Laycock 1979; Carr 1968).

Mechanical methods for controlling sagebrush are reviewed in Pechanec, et al. (1979), Blaisdell, et al. (1982), Parker (1979), and Laycock (1979). Although the most expensive means of sagebrush control, mechanical methods may provide the best means of control and seedbed preparation, especially for the best sites.

Whether seeding treated areas with adapted species is necessary depends upon the control method used, and the types and abundance of understory plants. Some portions of the study area, such as in Parker Hollow pasture, probably have sufficient understory to respond to most treatments without seeding. Where seeding is performed, best results are achieved when seed is covered with soil, preferably when drilled into a prepared seedbed (Laycock 1982; Laycock 1979; Vallentine, et al. 1963). Sometimes good results are obtained when seed is broadcast onto burned areas right after the burn. When controlling sage by railing or chaining,

seed may be broadcast ahead of the control activity. It is generally recommended that at least 50% more seed be used when broadcast seeding than when drilling seed (Plummer, et al. 1968). Fall seeding is probably best, before the first rain, unless seeding equipment can go onto the site before soil moisture is significantly depleted in the spring (Laycock 1982; Laycock 1979). Excellent reviews of seeding guidelines may be found in Keller (1979), Laycock (1982), Plummer, et al. (1968), and Blaisdell, et al. (1982).

The advantages of using adapted introduced species for seeding rangelands were reviewed under recommendations for aspen, above. The following seeding mixture is recommended for seeding areas where sagebrush has been controlled:

	<u>Pounds</u> Eastern <u>Pastures</u>	S/Acre Western Pastures
Fairway crested wheatgrass (Agropyron cristatum)	4	1
Intermediate wheatgrass (Agropyron intermedium)	3	4
Pubescent wheatgrass (Agropyron trichophorum)	1	1
Smooth brome (Bromus inermis)	1	3
Siberian wheatgrass ( <u>Agropyron sibiricum</u> ) or Russian wildrye ( <u>Elymus junceus</u> )	1	1
Alfalfa (Ladak, Nomad, Rambler varieties)	1	1
Other legumes (e.g., small burnet or yellow sweetclover)	1	1

(See Plummer, et al. 1968; Vallentine 1980; Blaisdell, et al. 1982; Winward 1980; Winward 1982; Frischknecht 1978; Vallentine, et al. 1963.) This seed mixture is recommended for broadcast seeding on burned sagebrush areas.

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